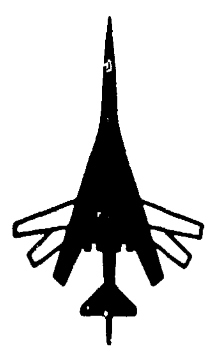
SUPERSONIC TRANSPORT PROGRAM
PHASE 11C
MONTHLY TECHNICAL PROGRESS LETTER REPORT

CONTRACT FA-SS-66-5

JULY 1965



D6-17488-7

THE BOEING COMPANY

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I SUMMARY OF PROGRESS

Significant progress accomplished during July 1965 is summarized in the paragraphs that follow.

A. WING TRAILING EDGE REFLEX STUDIES

Preliminary studies have been conducted on aerodynamic improvements in the 733-290 wing configuration by incorporating a reflex in the trailing edge airfoil section. A drag improvement of $\Delta C_d = .0013$ was indicated by one of the wing modification studies, which would yield about a 35 n.mi. range improvement.

A more comprehensive investigation of wing trailing edge reflexing is being undertaken in which a new digital computer program will be used. Modifications will be made in the high speed wind tunnel model for test verification of the analytical results.

B. FLIGHT DYNAMICS

Flight simulator and analytical studies of stability augmentation requirements that have been conducted to date indicate that stability augmentation will not be required for safety-of-flight at high altitude and high mach number conditions.

Comprehensive investigation is underway on establishing airplane handling characteristics and stability augmentation requirements to enhance the handling qualities at all critical flight conditions.

C. PIVOT BEARING TEST PROGRAM

(1) Full Scale Test

Testing of the full-scale pivot bearing was stopped at 18,474 cycles when a crack was discovered in one of the pivot support inboard lugs. Photostress investigations have been made and more are planned to thoroughly explain the failure and to establish a satisfactory repair design. Strain gage and photostress techniques will be used as a check on the repair before the test program is resumed.

(2) Quarter-scale Testing

The quarter-scale pivot test specimens continue to demonstrate excellent life characteristics. One of the specimens with a new epoxy adhesive has now successfully completed 332,200 cycles, which is compared to a previous high of 230,000 cycles completed on another specimen.

D. MANUFACTURING HARDWARE DEVELOPMENT PROGRAM

Detail design work is proceeding on the wing center section lower panel. This assembly will be approximately 23 feet long (wing pivot to

airplane centerline) and 12.5 feet wide (front to rear spar). The Ti 6AL-4V raw material has been ordered and detail drawings for some of the parts have been completed.

Initial drawings of the crew compartment windshield post and sill structure for the quarter cab section have been completed and released to manufacturing. In addition, drawings for a typical body frame have been completed and released to manufacturing.

E. CABIN ENVIRONMENTAL CONTROL TESTS

Tests have continued on the perforated ceiling type cabin air outlet. It was found that the fully perforated ceiling does not provide adequate air velocities throughout the cabin. A partially perforated ceiling was tested which demonstrated adequate cabin air velocities and maintenance of comfortable temperatures.

A failure condition was investigated, with simulation of two-pack-out operation. The average cabin air temperature rise was only 6°F in five minutes which demonstrated that safe cabin air temperatures can be maintained during the time interval between loss of a pack and attainment of subsonic speed.

F. TITANIUM

New results from titanium alloy high temperature exposure tests have shown that the high temperature stress corrosion problem in titanium alloys is not as serious as previously believed.

Previous testing has been based on laboratory conditions much more severe than those of typical SST service life. The principal difference between the two conditions relates to time at temperature. The laboratory conditions held high temperatures for protracted periods, several hundred hours in many cases. However, typical SST operating conditions involve hot periods of 2.5 hours or less on a typical flight followed by a cool period at low speed or on the ground.

It has been found that titanium dichloride is formed on the metal under high temperature conditions when the metal is exposed to salt and this is the reactive agent in creating stress corrosion. However, protracted periods at high temperatures are required before this action takes place.

Titanium dichloride is highly unstable and quickly dissipates under cooling conditions. Therefore, it has been found in the laboratory, that under alternating hot and cold conditions, titanium alloys are not subject to high temperature stress corrosion.

Work is continuing on the environmental fracture toughness problem of titanium alloys that has been reported previously.

II PROBLEM REPORT

A. LANDING-GEAR-INLET

The Boeing SST will incorporate a landing gear deflection system and the landing gear doors will be designed such that no foreign objects dislodged or displaced by the landing gear will enter the engine inlet. Preliminary investigations carried out in Phase IIB on a .4 scale model of the 733-347 landing gear indicate that the gear could operate through water depths up to 1 1/2 inches in depth and no water would enter the engine inlets. Part III of this test series will add an operating inlet in the inboard position (lowest engine) and a further definition of the problem and its solution will be obtained. At the present time the system weighs about 1100 lbs. and flight tests of the prototype airplane may show it to be unnecessary.

B. JET EXHAUST INTERFERENCE EFFECTS

Preliminary wind tunnel test data obtained on a half model and simulating the jet exhaust flow with cold air have indicated a pronounced jet exhaust interference effect on stability and control. (June Progress letter). This effect appears detrimental for downward tail deflections and beneficial for upward tail deflections. These static airplane characteristics have been simulated including all the nonlinear variations. The tendency of the pilot would be to overcontrol during the takeoff maneuver because the jet exhaust interference has about doubled the pitching moment increment due to tail deflection. This is a problem in airplane dynamics and will be continuously evaluated. A more complete model with 4 simulated engines operating is scheduled for testing early in August. This large full-span model has 4 kerosene burners for producing simulated engine exhaust characteristics. The inlets are covered over but the effects of inlet flow are expected to be small at speeds up to M = 0.3. A further refinement in test techniques will indicate whether any horizontal tail relocation or resizing will be necessary to minimize the jet exhaust interference effects on stability and control.

C. PRIMARY FLIGHT CONTROLS

There has been and continues to be a high level of effort on the primary flight controls. The system size, power required both due to size and rate, complexity, and reliability are serious design problems. A new addition to the problem has been encountered as a result of preliminary horizontal tail flutter investigations. Substantial design effort and aerodynamic analysis has been expended in an effort to reduce the hydraulic power required for the 733-362 tail. Recent tests have been shown that the previously indicated high power levels are very likely required for the slab tail to prevent flutter. A re-evaluation of several longitudinal control systems previously studied is underway including their relative stiffnesses as it pertains to flutter.

II Problem Report (continued)

D. TITANIUM

Ti 8AL-1Mo-1V particularly in thick sections, has been shown to develop a serious loss in fracture toughness in a water or salt environment. As a result, an intensive effort is underway to find an improved titanium alloy. A large quantity of Ti 6AL-4V, and 4AL-3Mo-1V is now available and under test.

It is estimated that the properties of 6AL-4V are sufficiently established to allow construction of the prototype airplane; however, it is believed that important improvements in titanium alloys can be made and developed before start of production. New alloys such as 5AL-3Mo-1V-2 and 6AL-2Mo are being fabricated for test. It is anticipated that a better definition of the alloys will be available in the fall of 1965 and recommendations will be forthcoming at that time.

III. DESCRIPTION OF TECHNICAL PROGRESS

10 AIRFRAME -- GENERAL

1001 Systems Integration

10011. CONFIGURATION DEVELOPMENT

(1) Landing Gear Debris Deflector

The wave patterns formed by the 0.4 scale landing gear were studied and the effect of velocity and water depth on bow wave angle determined. Scale depths of 0.2 to 0.6 inches were used, corresponding to full scale depths of 0.5 to 1.50 inches. The range in bow wave angle indicated that a change in the forward portions of the full deflector would be required to contain the bow wave as shown on Fig. III-1. The "boiler plate" full deflector shown contains the water for all speeds run and water depths tested. Figure III-2 shows a 0.2 inch depth of water at 43 mph, simulating 0.5 inch and 60 knots full scale. The two rings simulate 0.4 scale inlet locations.

Partial deflectors designed to deflect specific portions of the wave are being designed and tested. The information obtained will be used to refine the full deflector design.

Part III test planning is nearing completion.

(2) Performance Analysis

Work has been initiated on determining the optimum cabin cruise altitude for the Model 733-362 airplane. The present cabin cruise altitude of 6000 feet is the result of an earlier study on a different configuration which considered design range (4000 statute miles) only. It results in a normal descent time of 20 minutes at the limit cabin rate of descent of 300 feet per minute dictated by passenger comfort. The current study will include consideration of cabin cruise altitudes of about 3000 feet to 8000 feet at ranges from about 1000 to 4000 statute miles in order to determine the best choice of cabin cruise altitude with respect to Direct Operating Cost, passenger comfort (deceleration, body attitudes, etc.), and air traffic control requirements (speed, rate of descent, etc.).

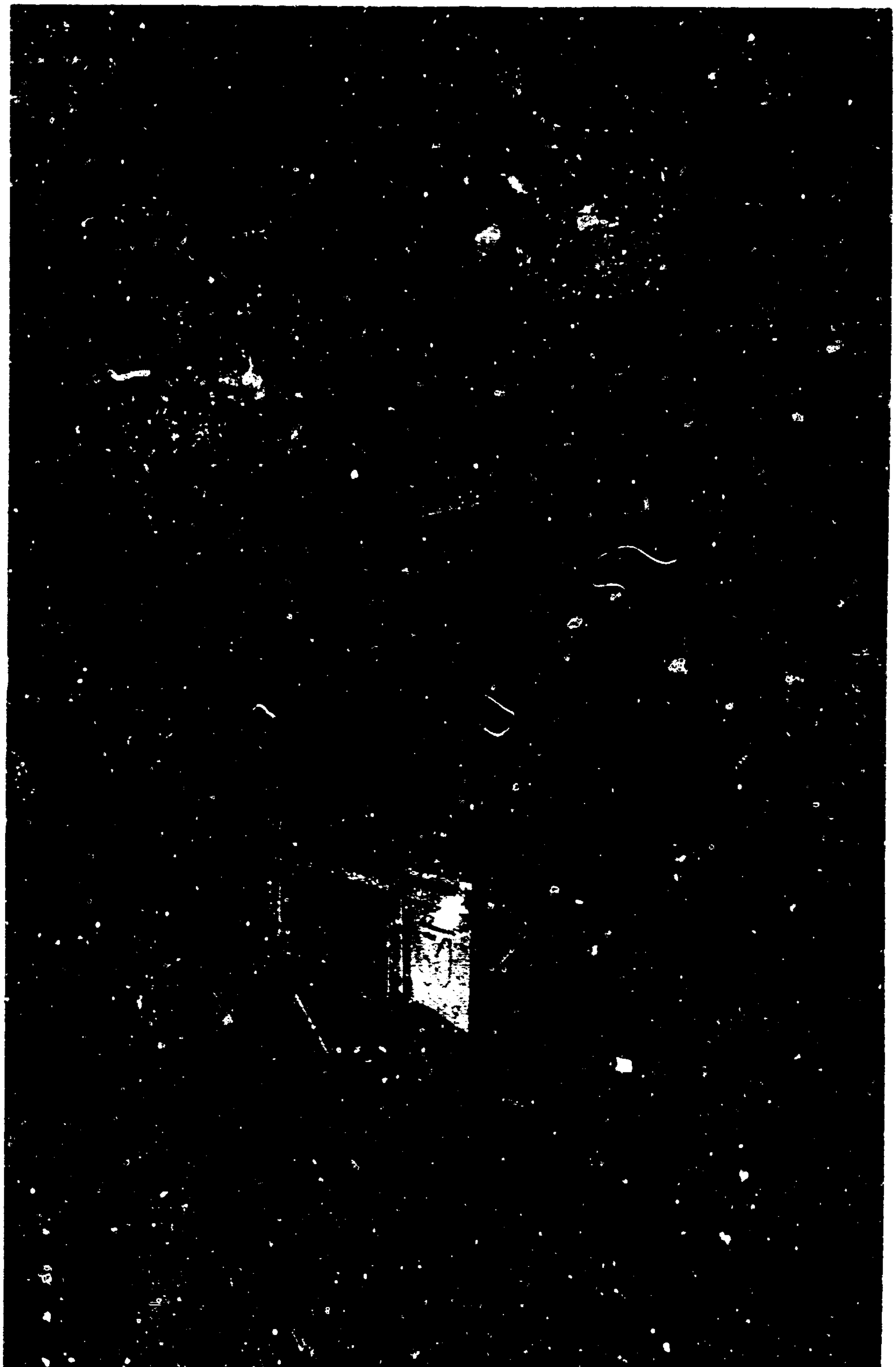

Fig. III-1 Landing Gear Debris Deflector Tests

Fig. III-2 Landing Gear Debris Deflector Tests

III Description of Technical Progress (continued)

1002 Design Analyses

10021. AERODYNAMIC ANALYSIS

(1) High Speed Configuration

Wing Trailing Edge Reflex Studies

The present 733-290 wing was designed utilizing theoretically calculated nacelle interference pressure fields. However, measured data are now available and have formed the basis for a theoretical study of drag improvement through trailing edge reflex. Three modifications to the 733-290 wing have been investigated. Preliminary estimates indicate a drag improvement of $\Delta C_D = 0.00013$ for the example shown in Fig. III-3. The analytical studies on the shape of the wing trailing edge will be continued using a new digital computer program which has been completed and checked out. Modifications will be made to the high speed wind tunnel model to verify the analytical results.

Sonic Boom

Recent NASA wind tunnel tests on sonic boom have been analyzed in a continuing effc to maintain valid and up-to-date theoretical methods. The test data were obtained with a model of the SCAT 15F with a modified fuselage designed to produce low overpressures, and with a model designed to investigate the effect of wing-body interference on the sonic boom. The former model was designed and tested by NASA Langley, and the latter was designed and tested by NASA Ames.

Comparisons between the test data and the theoretical predictions for each model are shown in Fig. III-4. The agreement shown for the Modified SCAT 15F model in the upper plot is very good. The lower plot indicates excellent agreement for the low wing model and is not quite as close for the high wing model although the trend between the data and the theory is quite similar. Reasons for the lack of agreement in the absolute level of the high wing model are presently being sought.

10022. FLIGHT DYNAMICS

Design analysis work is continuing on the automatic flight control system. Work is underway to establish airplane handling characteristics and the type of stability augmentation required at all critical flight conditions. Flight simulator and analytical studies conducted to date indicate that stability augmentation will not be required for safety-of-flight, but that a highly sophisticated system will be required for good handling qualities in the high Mach number, high altitude environment.

10024. AERODYNAMIC WIND TUNNEL TESTS

Testing completed in July and programmed through October is shown on the schedule chart, Fig. III-5. Wind tunnel occupancy time for aerodynamic tests totaled 200 hours during July.

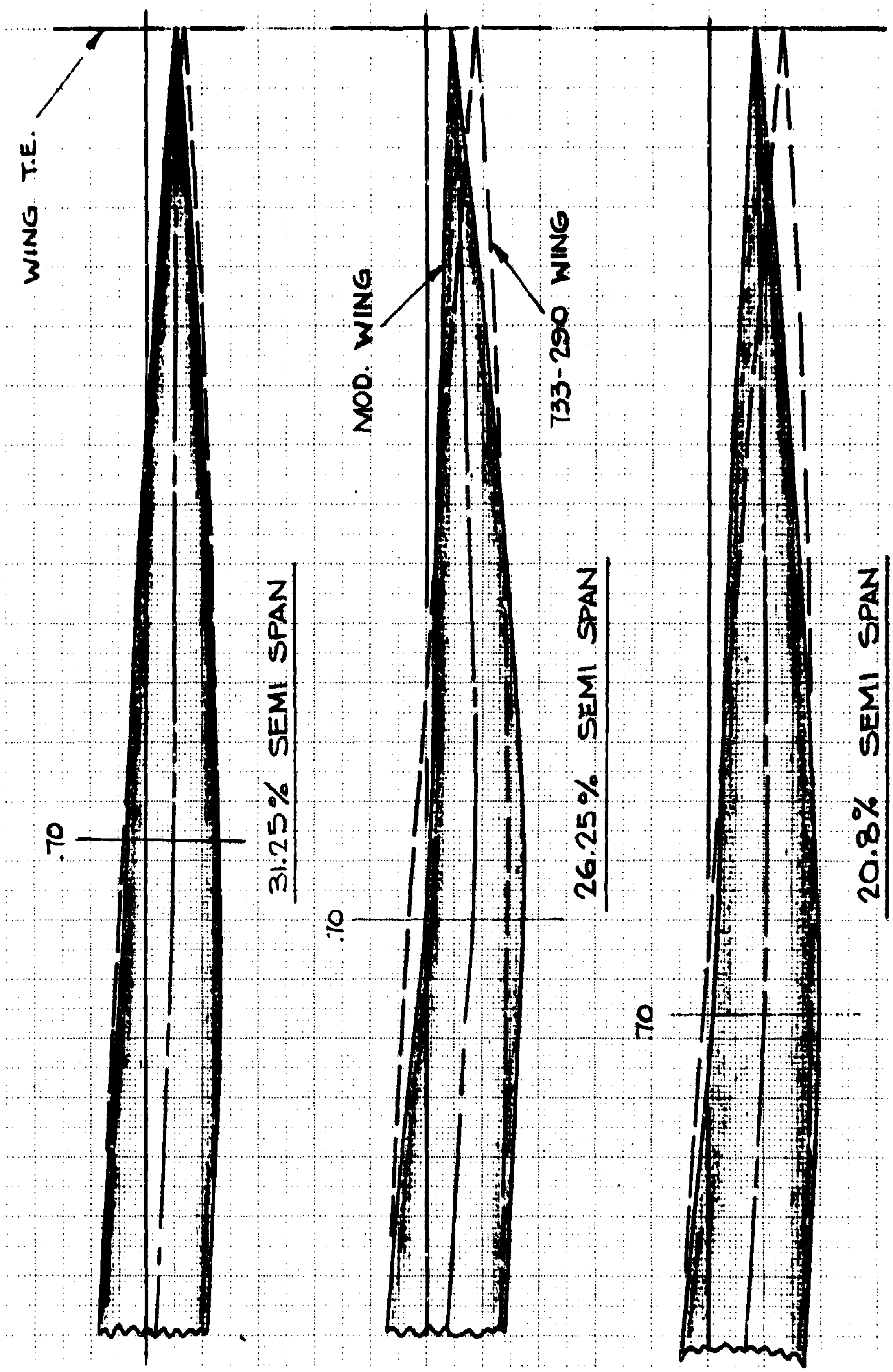

Fig. III-3 Trailing Edge Reflex Study

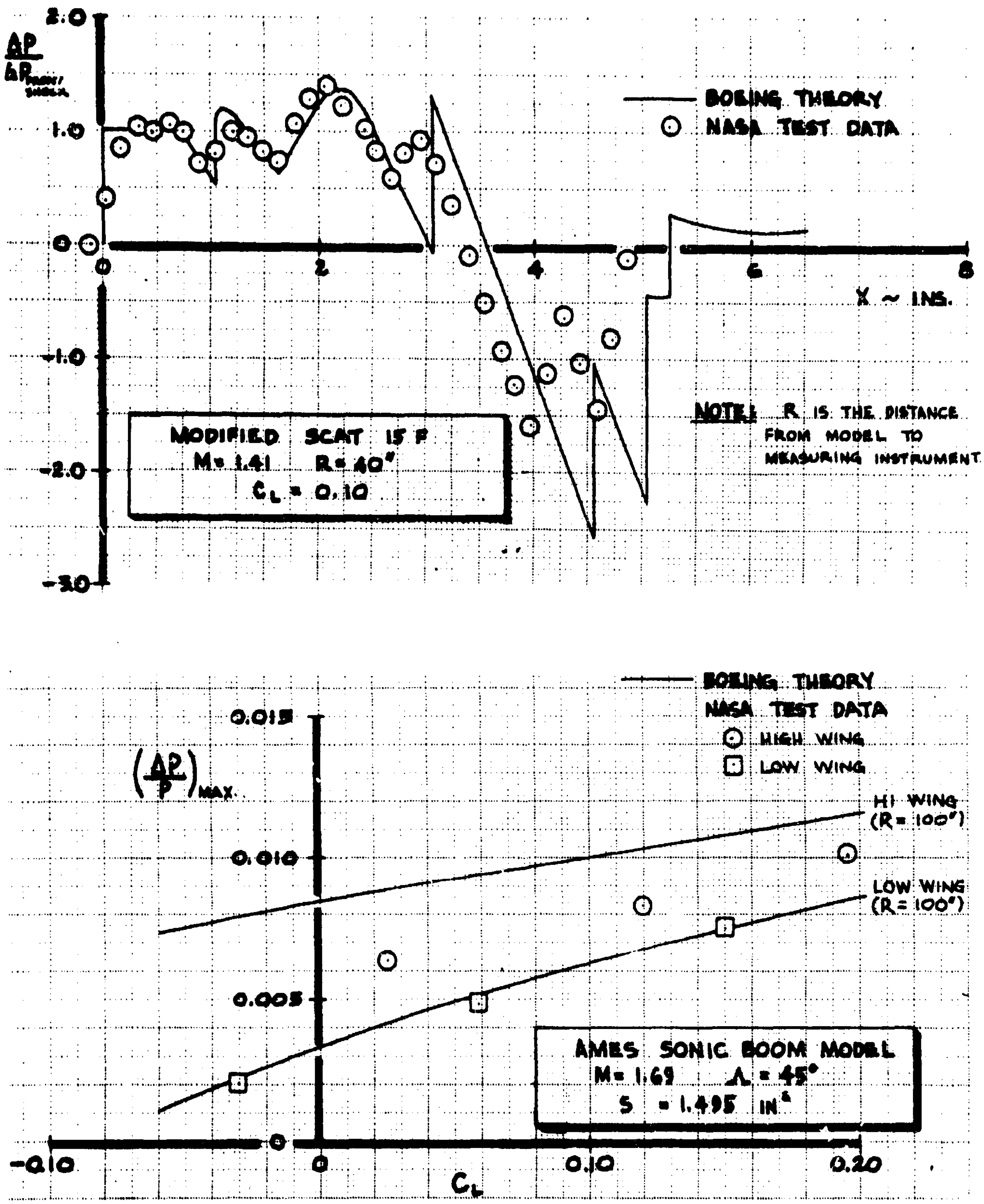

Fig. III-4 Comparison of Sonic Boom Test and Theory

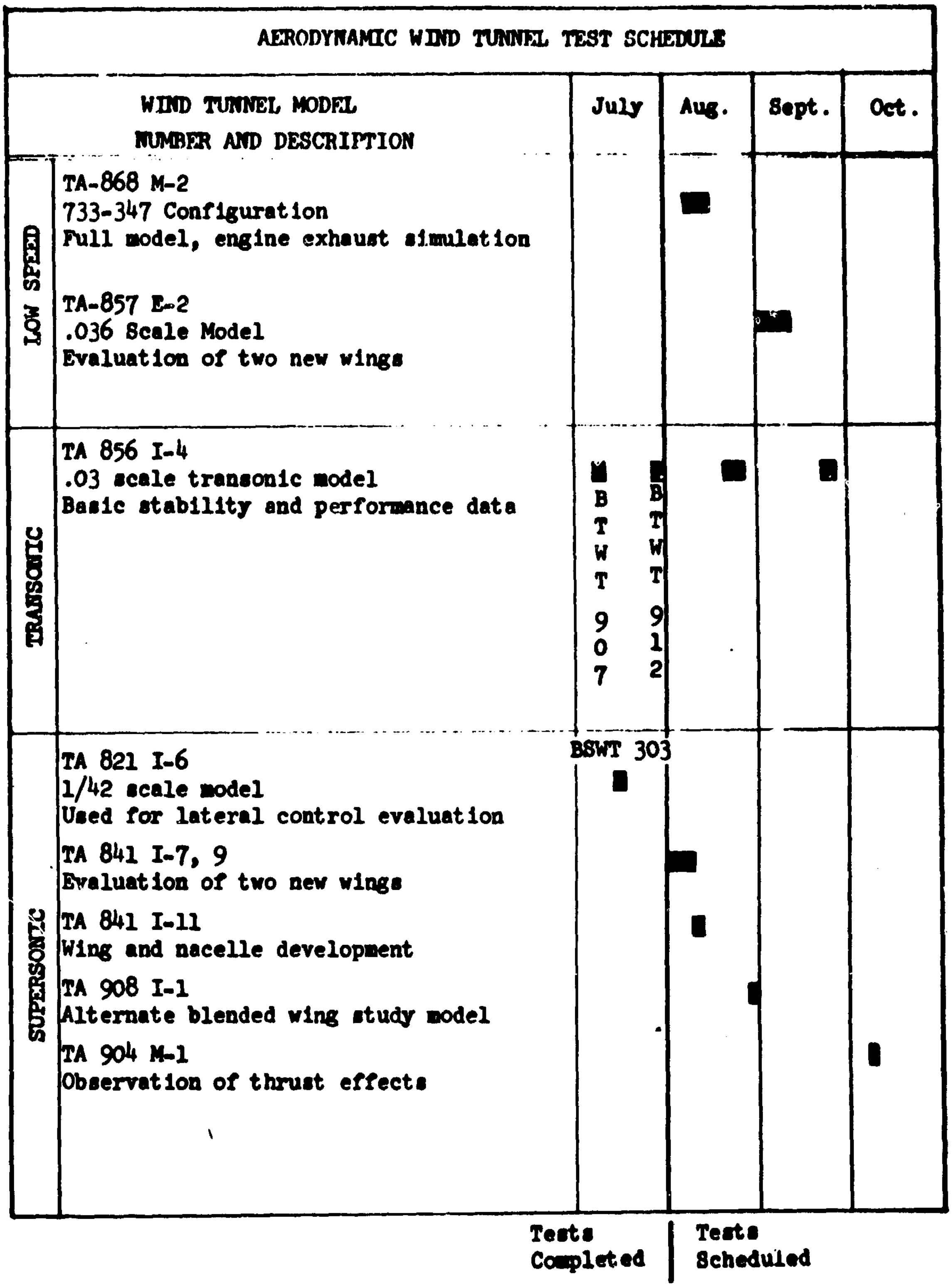

Fig. III-5 Aerodynamic Wind Tunnel Test Schedule

III Description of Technical Progress (continued)

(2) Tests Completed

Boeing Transonic Wind Tunnel Tests No. 907 and 912; TA 856 I-4, 0.03 scale model. Tested July 8 through July 14, and July 27 through July 30. Purpose: To continue the evaluation of subsonic and transonic aerodynamic characteristics initiated during May in the Cornell Aeronautical Lab. These tests will also provide a correlation of Cornell and Boeing wind tunnel results.

Boeing Supersonic Wind Tunnel Test No. 303; TA 821 I-6, 0.024 scale model. Tested July 21 and 22. Purpose: To evaluate 733-347 and alternate configurations lateral control effectiveness at supersonic speeds.

(3) Future Test Plans

Testing scheduled for August will provide valuable data in all three speed ranges -- low speed (flaps down), subsonic cruise, and supersonic cruise. The low speed testing will utilize the new 0.055 scale model which was designed primarily to match the 733-347 configuration. This model has been built in order to develop the flaps and high lift system more carefully than the previous TA 788 model permitted. Provisions for testing of blown flaps or slats at a later date are included in this model. A plenum chamber is being built into the wing strake area. In the August test, engine exhaust simulation will be provided by kerosene burners in the four nacelles.

Testing of the TA 856, 0.03 scale transonic model will continue in August at the Cornell Aero Lab. A principal item in the planned tests will be a new outer wing panel built to simulate the spanwise deflection and twist distribution of the cruise (72 degree) wing.

Two wings of the 733-290 planform, but with different twist and camber, will be tested in the supersonic wind tunnel. These models will assist in further optimization of the arrow wing, with the local twist distribution providing benefits to low speed performance.

10025. FLIGHT SIMULATOR

A dynamic simulation of the takeoff rotation and climb-out maneuver has been developed at the Boeing SST flight simulator facility. Airplane stability and control characteristics were simulated. Preliminary data from wind tunnel tests involving measurements of jet exhaust interference effects were included as functions of control deflection, angle-of-attack, height above the ground, and engine thrust level. The simulated airplane characteristics included all the non-linear variations of lift, drag, and pitching moment with ground height, angle-of-attack, and control deflection.

The initial evaluations of the takeoff maneuver obtained to date indicate that moderate overcontrol problems may exist if thrust effects on pitching moment are large. The jet exhaust interference data used in the simulation are preliminary in nature, since cold jets were used on a half model. Further flight simulation will be conducted when additional data are available from wind tunnel tests using hot jets (kerosene burners) on a full model (0.055 scale).

11 AIRFRAME STRUCTURE

1100 Airframe Structure -- General

11001. TITANIUM ALLOY DEVELOPMENT

A sufficient quantity of Ti 6Al-4V and Ti 4Al-3Mo-1V in the required gages is now available to conduct the investigation as proposed. Material will be drawn from that currently in Boeing stores, or scheduled on dock the first week in August.

All exploratory heat treatment cycles scheduled for Ti 6Al-4V and Ti 4Al-3Mo-1V have been completed. The Ti 6Al-4V tensile and notch bend specimens have been final-machined and 70 percent of the tensiles have been tested. Room temperature properites of the completed specimens reported below include data on the annealed, as received, 1/2 inch plate:

Table III-A Room Temperature Tensile Properties of As Received and Heat Treated Ti-6Al-4V

Code	Heat Treatment	Ultimate (ksi)	0.2% Yield (ksi)	R.A. (%)	Elongation in 1in. (%)
-	Annealed (As Received)	159.4	153.4	-	12
		159.6	154.3	-	16
Solution Treated and Aged (STA)					
A1	1550-2hr-WQ + 1250-4hr	150.0	141.7	34	15
		149.6	141.1	39	16
A2	1600-2hr-WQ + 1250-4hr	151.2	143.8	38	15
		151.8	146.7	38	15
A3	1650-30 min-WQ + 1250-4hr	156.2	149.0	38	16
		154.2	150.2	38	16

WQ - Water quenched

All Others are air cooled

Table III-A Room Temperature Tensile Properties of As Received and Heat Treated Ti-6Al-4V (continued)

Code	Heat Treatment	Ultimate (ksi)	0.2% Yield (ksi)	R.A. (%)	Elongation in 1in. (%)
A4	1725-30 min-WQ + 1250-4hr	158.2	150.3	45	16
		158.2	150.9	43	15
A5	1725-30 min-WQ + 1000-4hr	180.6	171.2	41	12
		179.9	168.6	46	14
A6	1725-30 min-WQ + 1150-4hr	168.1	162.4	43	16
		168.5	163.2	43	16
A7	1725-5 min-WQ + 1250-hr	158.2	154.3	40	15
		-	-	-	-
A8	1725-6hr-WQ + 1250-4hr	155.9	153.1	43	16
		155.8	153.6	40	15
A9	1725-30 min-WQ + 1000-1hr	181.1	169.4	44	13
		181.1	170.4	43	11
A12	1725-30 min-WQ + 1250-1hr	165.3	159.7	44	14
		164.6	157.9	46	16
A15	1550-2hr + 1250-4hr	150.8	146.2	35	15
		151.9	146.0	33	14
Annealed					
B2	1300-2hr	154.2	142.0	38	12
		151.7	146.2	44	15
B3	1400-2hr	149.2	144.3	39	15
		151.4	145.8	40	15
B4	1500-2hr	151.7	145.4	42	15
		151.8	145.3	38	14
B7	1300-6hr	150.9	144.7	41	16
B10	1500-2hr + 1000-4hr	157.2	148.7	39	14
		156.7	150.3	39	14
Prior Beta Annealed					
C1	1850-30 min-WQ + STA #1	173.7	159.4	27	10
		173.7	157.5	17	7
C2	1925-30 min-WQ + STA #1	180.3	161.3	13	6
		179.0	158.7	14	7
C4	1850-30 min-WQ + STA #2	160.1	145.1	21	10
		159.9	146.0	17	9
C5	1850-30 min-WQ + STA #2	160.9	147.7	16	7
		161.3	150.6	17	7
C6	1925-30 min-WQ + STA #2	161.8	148.8	18	8
		163.0	147.4	18	9
C7	2000-30 min-WQ + STA #2	163.9	147.2	20	7
		160.1	147.6	19	9

NOTE: All Tests Are Transverse
STA #1 = 1725 - 30 min-WQ + 1000-4hr
STA #2 = 1725 - 30 min-WQ + 1250-4hr

Approximately 50 percent of the Ti 4Al-3Mo-1V specimens for heat treatment study have been final machined. Nearly all Ti 6Al-4V notch bend specimens have been precracked and are scheduled for test during the first half of August.

11004. STRUCTURAL DESIGN CRITERIA

(1) Full Scale Bearing Test

Cycling of the test bearing under room temperature conditions was stopped at 18,474 cycles when a crack was discovered in one of the pivot support inboard lugs. The crack, approximately eight inches long, eminated from the corner of the lightening hole inboard of the bearing and progressed toward the bearing plug hole. Photostress investigations, utilizing plane plastic models, are being conducted to ascertain the most desirable rework of the lightening hole. The photostress clearly shows a high stress level at the point of failure when the specimen is loaded in the aft wing position.

Cycling will resume upon completion of the lug repair. The rework will utilize fusion-welding similar to that used in the original fabrication. The effectiveness of the lightening hole rework will be confirmed on the specimen by strain gage and photostress techniques.

(2) 1/4 Scale Pivot Test

The Number 6 (lower surface) and Number 8 (upper surface) bearings have accumulated 332,200 and 214,400 cycles respectively. Both bearings show good life compared to the previous high time of 230,000 cycles on other bearings.

(3) Two-Inch Bearing Test Program

Testing of teflon-glass bearings bonded with AF-31 adhesive has been halted. The fabrication process control has been extremely critical and the test results have indicated poor reliability. The possibility of these bearings providing long life at 300°F is remote. Vendor bearings fabricated with similar adhesive systems have also been subject to considerable variation in test results and the results have been poor after exposure at 300°F.

With the deletion of AF-31, all specimens will utilize teflon-glass bearings bonded with the Shell Chemical adhesive system. A fabrication specification has been initiated which will allow procurement of two-inch diameter bearings from the bearing industry for an evaluation of adhesive system reliability when used by several

different vendors. The limited test experience at Boeing has indicated that excellent bearings can be processed with a minimum of controls. Two tests have been completed on Shell adhesive teflon-glass bearings since the last report and four others are in test. Those completed are:

Spec. No.	Load Kips	Temp. °F	Prior Exposure at 300°F - Hrs.	Bond Line Thickness(In.)	Wear-Life Cycles	Wear-Life Feet
220	20	70	None	.0114	686,876 [1]	129,900
221	10	-65	None	.0102	122,485	23,520

[1] Failure of test shaft initiated bearing failure.

(4) Sonic Fatigue Testing

Testing of the variable support, spotwelded skin-stiffener panel (Panel D, Page 48, of the April Report) has been completed. Data was obtained for support spacings of 10, 15, and 20 inches in each of three mounting positions, (Ref. D6-17488-6) and indicates the following:

- Stiffener spacing is the primary contributing factor to stresses in the panel. The panel with stiffeners at 5.40 spacing had stresses approximately two times the panel with 4.33 spacing.
- Reducing the stiffener support spacing from 20 inches to 15 and 10 inches reduces the stresses in the stiffeners but, does not significantly reduce the stresses in the skin.
- The panel mounted with the sound waves normal to the skin generated stresses approximately twice those from sound waves grazing the skin. Changing from a grazing incidence parallel to the stiffeners to a grazing incidence normal to the stiffeners changes the location and frequency of the skin stresses but does not significantly effect the stress magnitude.

(5) Structural Allowable Tests

Shear Panels

Testing has been completed on the IA and IIIA riveted stiffener shear panels (Ref. D6-17488-4, Page 60). Typical web failures were obtained for both panels at approximately the predicted web strength. The panels failed at 98 percent and 93 percent of predicted load respectively for the 0.025 and 0.050 webs.

Compression Panels

Tests have been conducted on the Type II panel at elevated temperature and on all except one Type III panel. (Ref. D6-17488-4, Fig. 3-21.) The Type II panel failed at 98 percent of the predicted load of 174 kips. The Type III panels were bowed as a result of the fabrication process and caused some eccentricity in the loaded columns. All failures occurred as a result of local crippling and at approximately the predicted allowable when the column eccentricity is taken into consideration. An end fixity coefficient of 3.5 was used to correlate all theoretical allowables with test results. Figure III-5 shows the fixed-ended panel test used to confirm the end-fixity of 3.5.

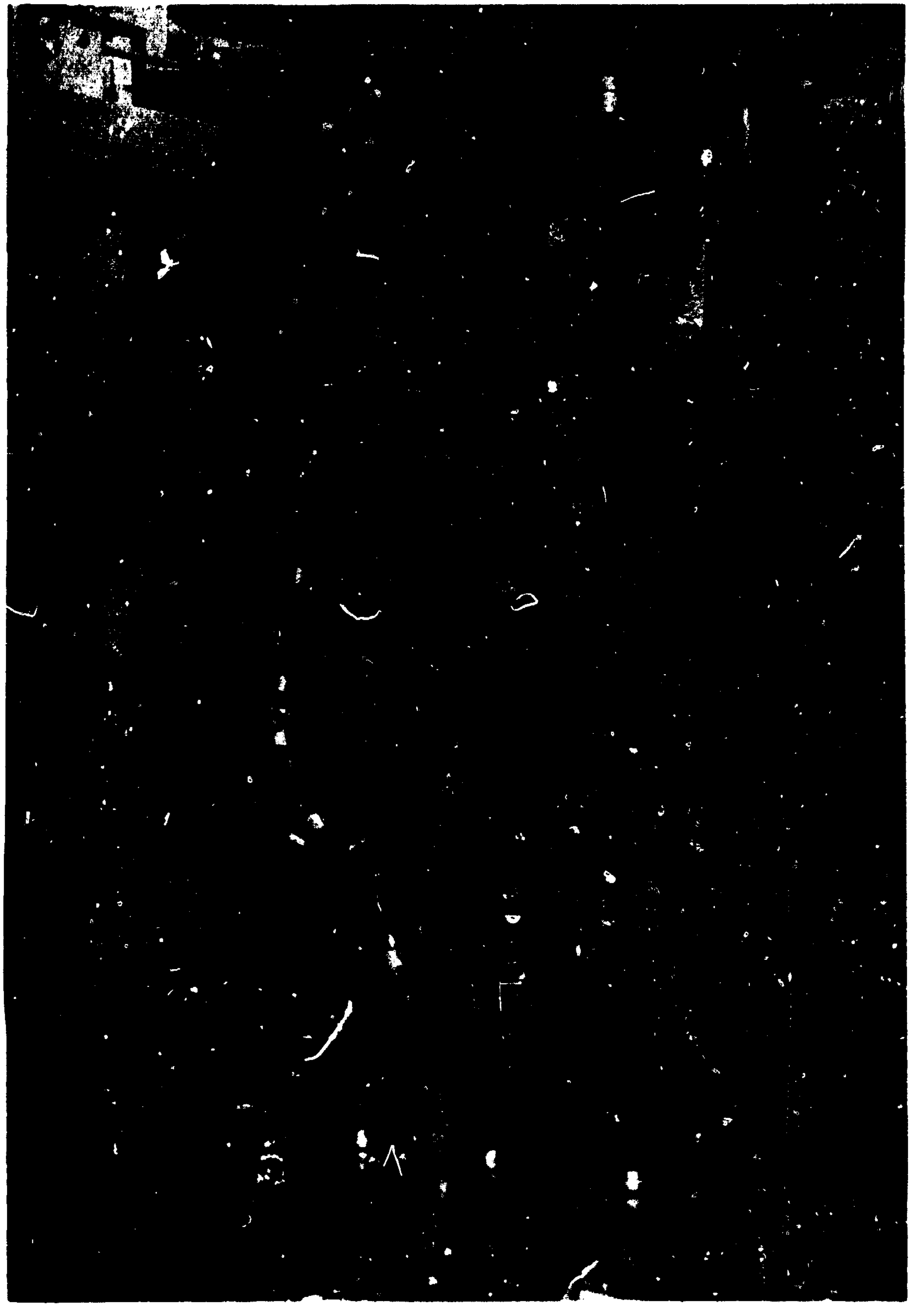

Fig. III-5 Compression Panel Testing

(6) Fatigue Tests

Three full scale Ti 8-1-1 panels have been fatigue tested. One panel represented a thin gage body structure with tear stoppers, and was identical to the one described in D6-17488-6, Page 93. This panel was tested at a maximum stress of 30 ksi and R = 0.06. At 30,500 cycles numerous small fatigue cracks were found in the skin at spotwelds common to the tear straps. The cracks were allowed to propagate and merge until complete failure occurred at 45,100 cycles. The second panel represented a wing lower surface basic structure configuration, and was identical to the one shown in Fig. 3-23 of D6-17488-5, Page 78. This panel was tested at 40 ksi maximum stress and R = 0.06. The first crack occurred in the skin at 76,900 cycles and was stop drilled. The second and third cracks occurred at 80,100 and 85,500 cycles and were also stop drilled. Conditions for subsequent fail-safe testing of this panel are being established. The third panel was the same as the second panel, except that spotwelds, rather than Hi-Lok bolts, were used to tie the stiffeners to the skin. For the test condition of 60 ksi maximum stress and R = 0.06, the first crack occurred in the skin at 50,900 cycles and was stop drilled. At 60,200 cycles, complete failure of the panel occurred from a crack which started in the skin at a different spotweld.

Three spotwelded Ti 8-1-1 baseline specimens have been fatigue tested at 500°F and R = 0.06. The two specimens at 60 ksi maximum stress failed at 52,000 and 62,000 cycles. The specimen at 40 ksi maximum stress failed at 241,000 cycles.

(7) Fail-Safe Tests

Wing and Empennage Structure

Testing has been completed on the spotwelded "Z" stiffener reinforced panel. The panel had five "Z" section stiffeners spaced at 4.45 inches on a 20-inch wide panel (Ref. D6-17488-4, Page 71). Crack growth and load distribution data were obtained while the skin crack was being extended from a 2.1-inch starter crack at a maximum gross area stress of 35 ksi and R = 0.05. At 4550 cycles and a crack length of 5.94 inches, the skin flange of the stiffener across the crack failed from fatigue. The remaining uncracked section of the stiffener was cut. The panel was then fatigue cycled at a maximum gross area stress of 25 ksi and R = 0.05 and crack growth and load distribution data were obtained for crack extension with the failed stiffener. At 5450 cycles, the crack had reached 7.0 inches in length. The panel was then loaded at a rate of 13.2 ksi per second and failed at a gross area stress of 60.6 ksi. The predicted gross area failure stress of the panel was 60.0 ksi. The panel failure is shown in Fig. III-6.

Fuselage Structure

A test was conducted on the 0.032 skin gage fuselage skin panel to evaluate crack growth for the condition of a failed fail-safe strap. A six-inch starter crack was centered between stringers at a frame station, completely cutting the fail-safe strap. The crack

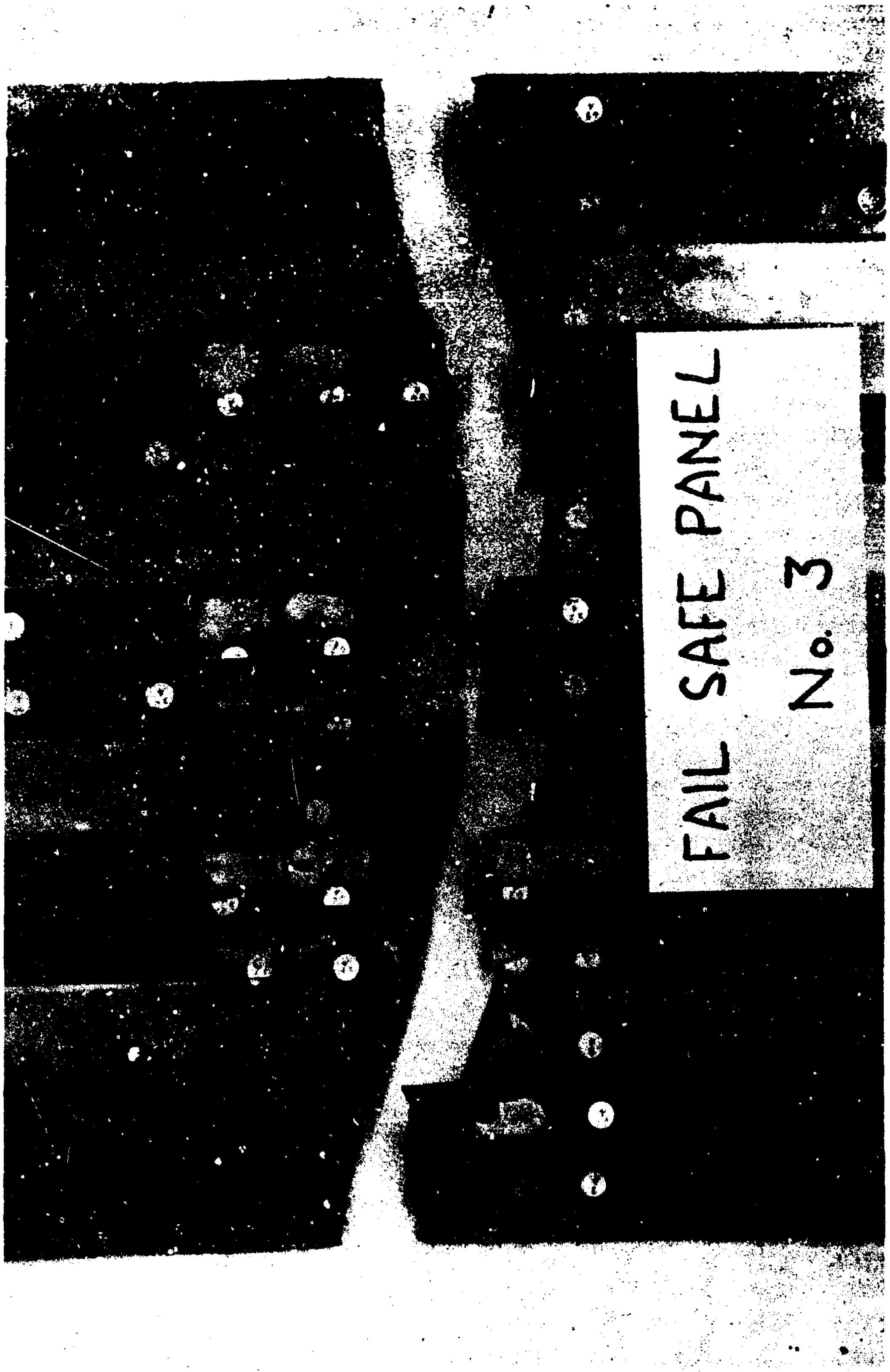

Fig. III-6 Fail-safe Test - Wing and Empennage Panel

growth obtained from pressure cycling the test section is shown in Fig. III-7. For crack extension up to 16.51 inches a maximum pressure of 13 psig was inadvertently used. At this point, the pressure was corrected to 12 psig. When the crack had reached 26.28 inches, a constant pressure loading of 12 psig produced a slow crack growth until arrested by the fail-safe straps. After the crack had been arrested at the straps, the maximum pressure loading was maintained for several minutes with no noticeable increase in crack length. The cracked area of the test panel is shown in Fig. III-8.

Testing of the number two fuselage panel was completed with this test and has been removed from the test section. The third fuselage test panel is being installed. Panel description and test outline for this panel is given in D6-17488-4.

11005. STRUCTURAL LOADS AND TEMPERATURES

(1) Thermal Analysis

A thermal analysis of the inlet centerbody support strut has been completed to determine the temperature distribution in the leading edge portion throughout the flight profile. The maximum and minimum structural temperatures during ascent and descent are shown in Fig. III-9. The stagnation temperature of the bleed air flowing internally through the struts is shown for comparison. The figure shows that only small thermal gradients are developed in the structure during the flight mission.

(2) Wind Tunnel Pressure Model

The TA-885 P-1 wind tunnel pressure model, shown in Fig. III-10 is complete and has been shipped to the NASA at Ames. Tunnel tests are scheduled to start August 9 in the 8 by 7 leg of the Unitary Tunnel.

1101. Wing

The layout and detail design of a production configuration wing center section lower panel has been a major effort during July. This panel assembly is roughly 23 feet long (wing pivot to airplane centerline) and 12.5 feet wide (front to rear spar). It consists of two large pivot area forgings which are fusion-welded to skin panels. This skin assembly, in turn, is reinforced by spanwise Z-section extruded stringers. This panel assembly is representation of the most severe forming for the wing contours. The design incorporates provisions for local concentrated loadings such as wing pivot actuator, landing gear, wing-to-body attachment, and power plant. All raw material is ordered (Ti 6-4) and detail production-type drawings of some components are complete.

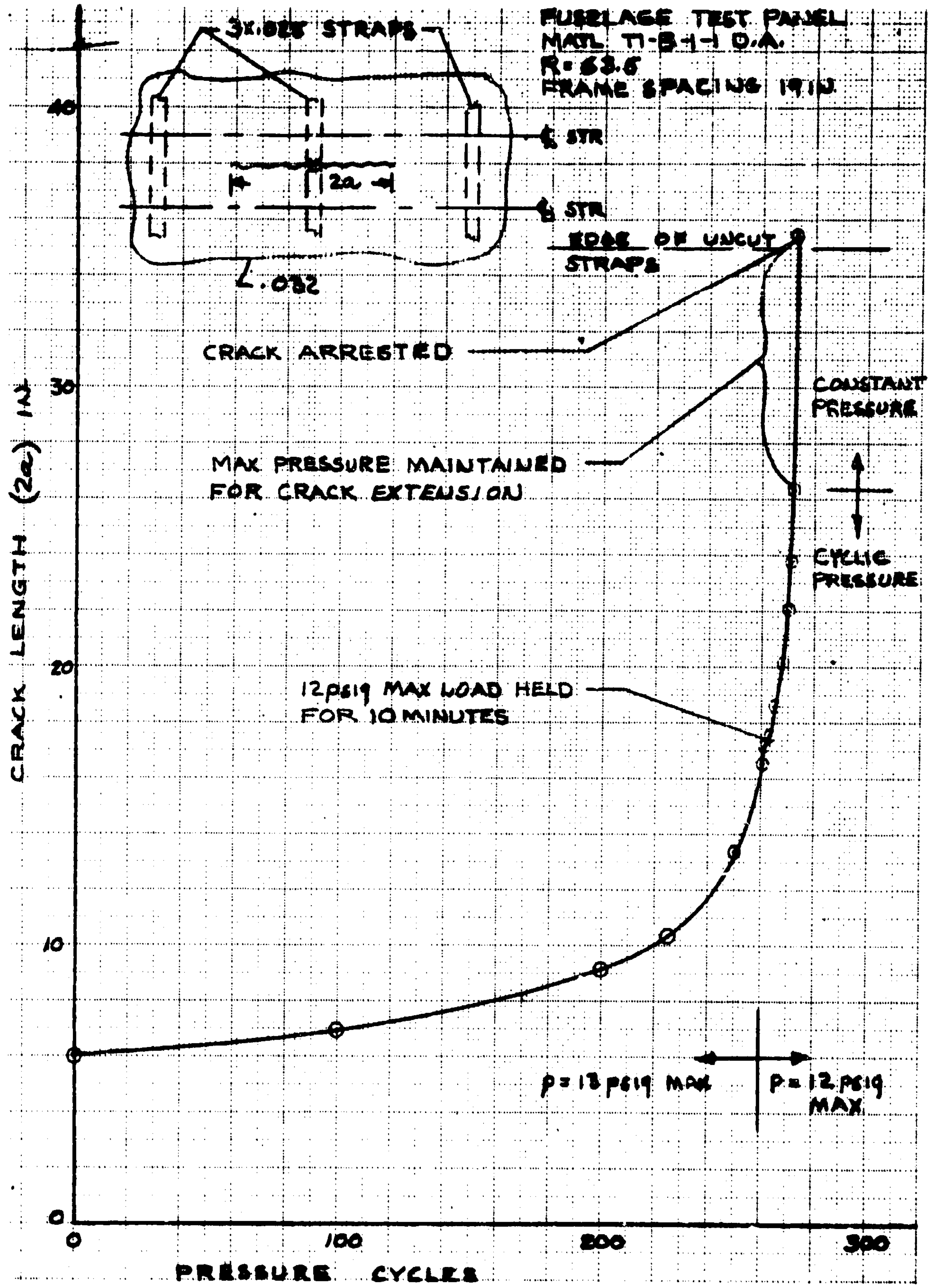

Fig. III-7 Crack Growth History - .032 Skin Fuselage Panel with Failed Strap

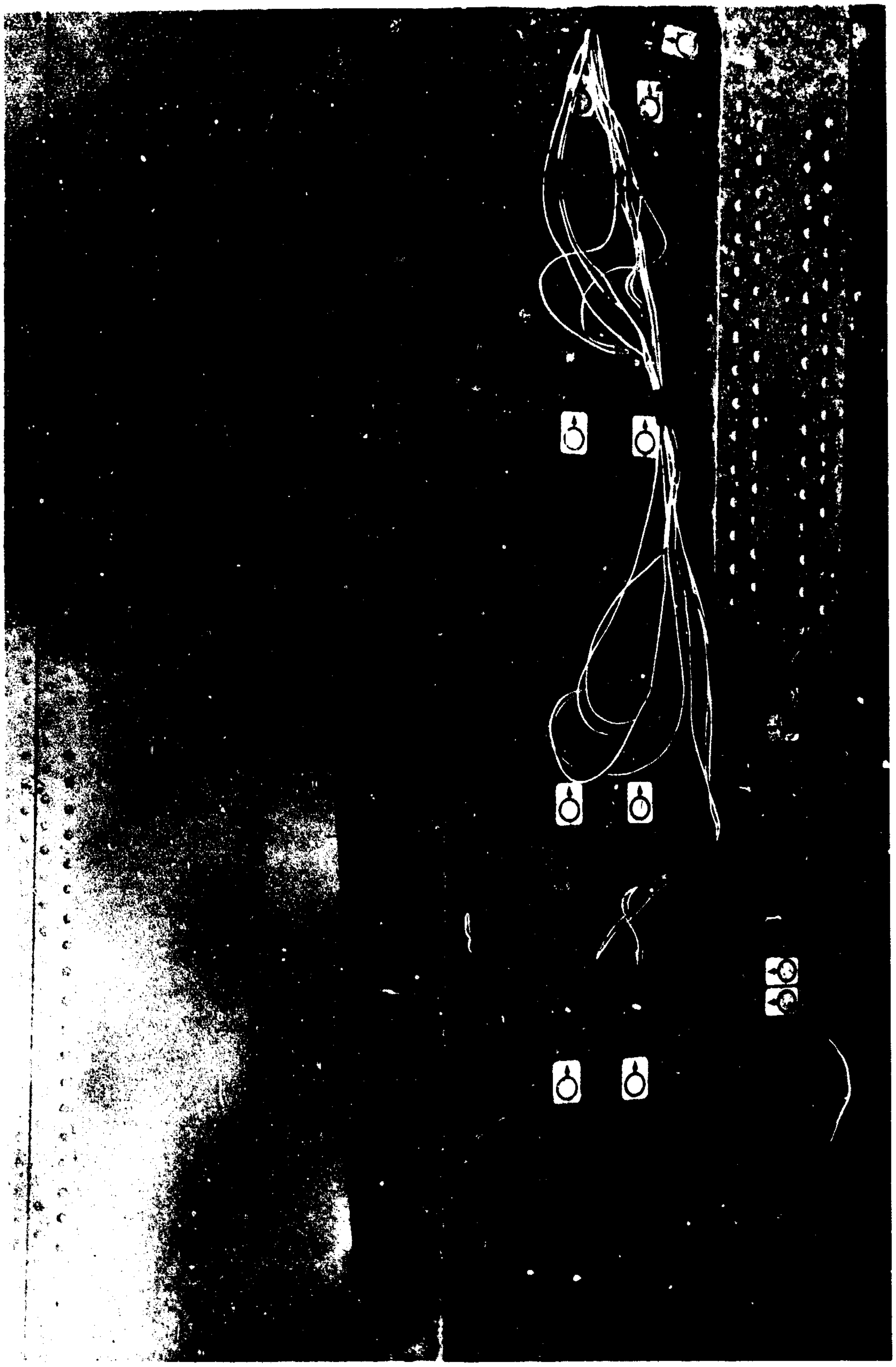

Fig. III-8 Fail-safe Test - Fuselage Panel

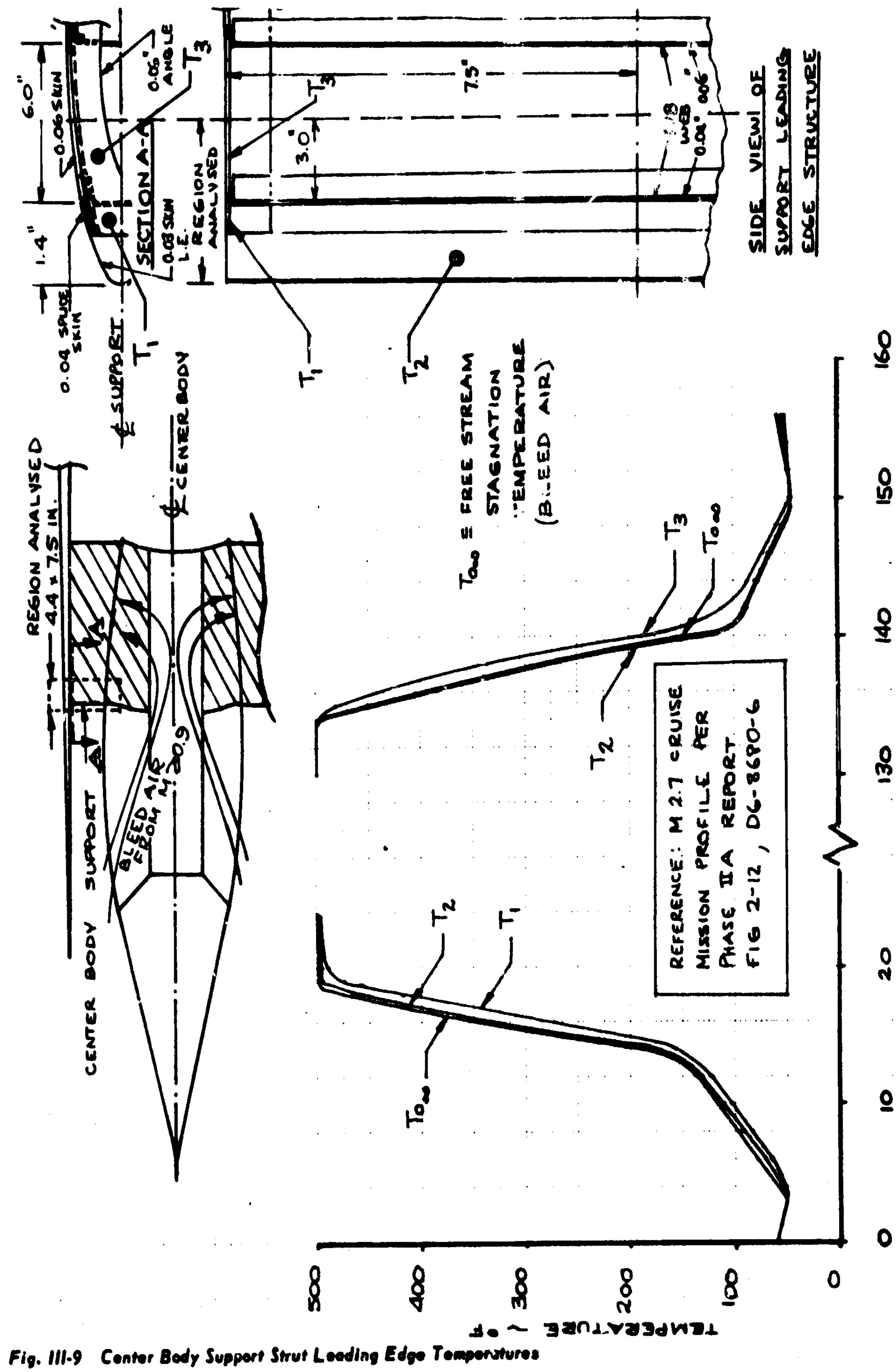

Fig. III-9 Center Body Support Strut Leading Edge Temperatures

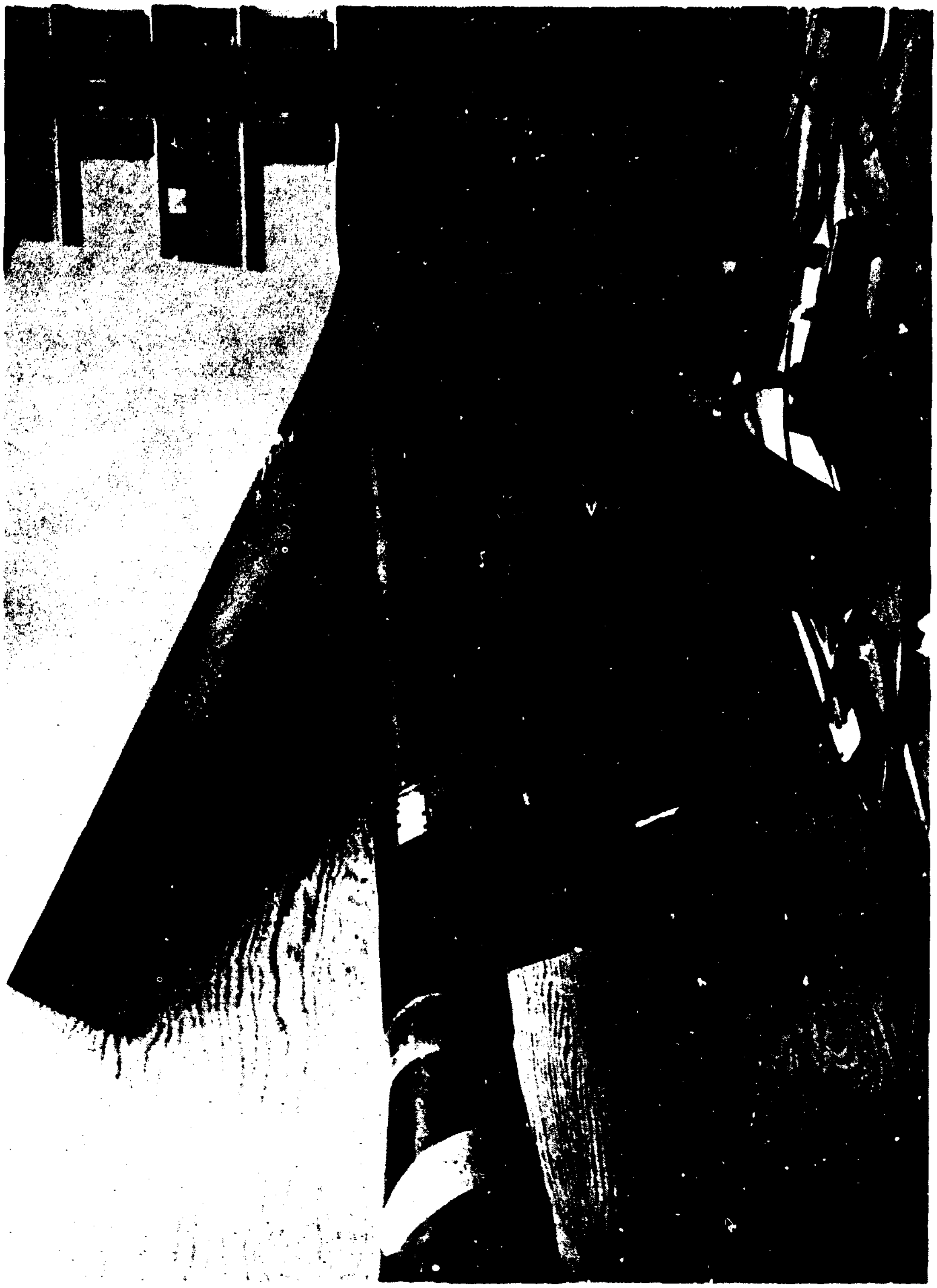

Fig. III-10 Wind Tunnel Pressure Model

1104. Fuselage

Design studies have been initiated to improve the movable nose geometry from a noise and vision standpoint. Initial drawings of the crew compartment windshield post and sill structure for the quarter cab manufacturing development hardware have been completed.

A typical body frame has been designed, detailed, and released for manufacturing development hardware.

1106. Landing Gear

Previous comparison studies of the eight-wheel and twelve-wheel landing gear configuration were inconclusive. Therefore, a twelve-wheel landing gear was retained on the 733-362 configuration. As was previously reported, the eight-wheel gear arrangement was lighter, but involved increased wing depth for stowage.

A study has been initiated to investigate 3 wing spanwise thickness ratio distributions to increase the depth at the gear stowage position. Airplane performance will be evaluated based on trades between weight, drag, sonic boom, and fuel location.

4. Empennage

Design effort on empennage structure has included preliminary studies of various horizontal tail positions and structural arrangements in an effort to minimize the body cutout dimensions and simplify the body seal.

12. AIRFRAME SYSTEMS

1202. Environmental Control

(1) RADIATION CONDITIONS

A study has been initiated to evaluate crew radiation exposure conditions on typical polar, equatorial, and north atlantic airline routes.

(2) SYSTEM OPTIMIZATION

The digital computer program for use in air conditioning equipment studies has been checked out and is now operational. The program will be used for continuing optimization of equipment and duct sizing.

III. Description of Technical Progress (continued)

(3) SURFACE AND WINDSHIELD ANTI-ICING

The feasibility of integrating the ice protection system for the engine cowl and inlet centerbody with the engine inlet system supplied by the engine manufacturer is being studied. The objective of this study is to simplify and reduce the weight of the ice protection system for the engine. Coordination with General Electric on this subject was initiated.

(4) CABIN AIR OUTLET AND PASSENGER CABIN THERMAL DEVELOPMENT TESTS

Tests have continued on the perforated ceiling type outlet and the initial configuration is shown in Fig. III-11. As reported in the June progress letter, this outlet configuration resulted in air velocities throughout the cabin that were lower than desired. The ceiling panel was modified to reduce the width of the perforated section from 35 inches to 17.5 inches as shown in Fig. III-12. This resulted in satisfactory air velocities throughout the cabin. An additional configuration was tested which had an 8.75 inch perforated section on each side of the ceiling with the center 17.5 inches closed off. With this configuration, velocities again were lower than desired in the seated passenger area. All the above tests were run "cold" (without external heating of the test section) and simulated a condition that would aspirate cabin air into the supply air near the intersection of the cabin wall and floor. From these preliminary tests, the center perforated 17.5 inch wide configuration was selected for the "hot" tests. The tests demonstrated satisfactory velocity distribution and comfortable temperatures in the seated passenger area.

A simulated failure condition was run to investigate cabin temperature transients. The condition established a three pack cruise condition as in the above "hot" test, then simulated in-flight failure of one cooling pack which reduced supply air flow and shut off the intrawall air flow. The average cabin air temperature rise was 6°F in five minutes which demonstrated that satisfactory cabin temperatures would be maintained during the time interval between loss of the pack and deceleration to subsonic speed.

All test data obtained to date is currently being evaluated in order to establish the next configuration for test.

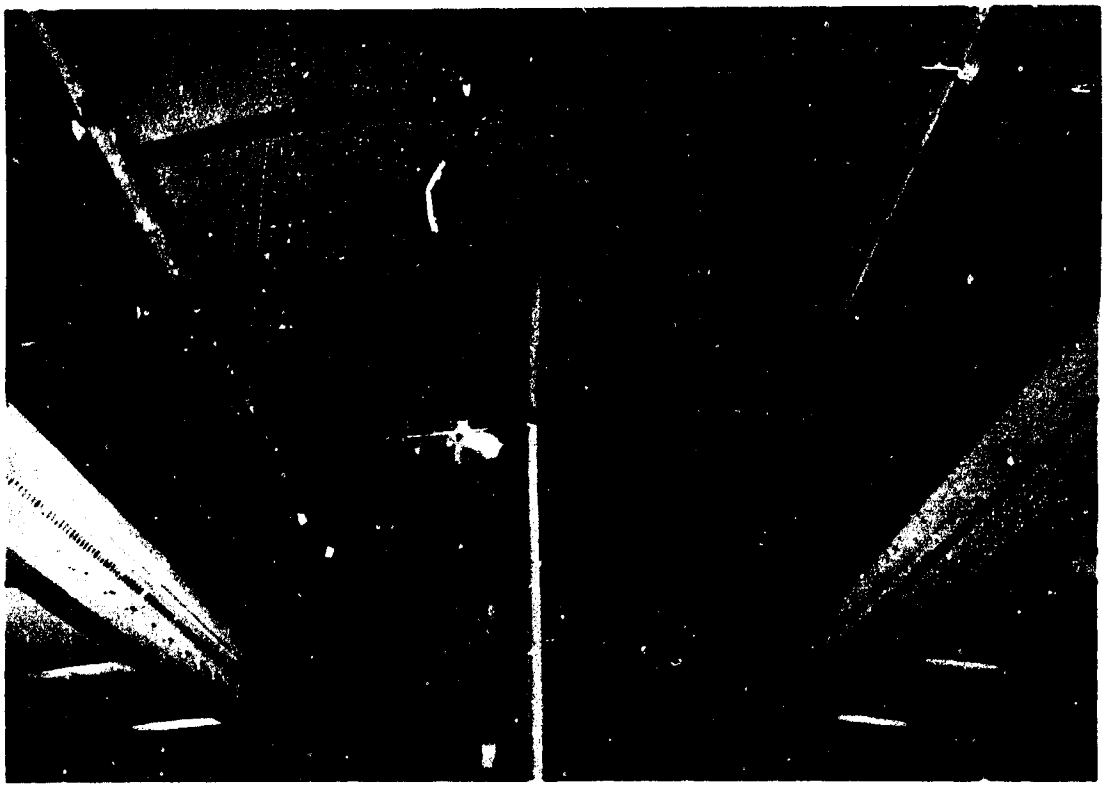

Fig. III-11 Cabin Environmental Control Tests - Perforated Ceiling

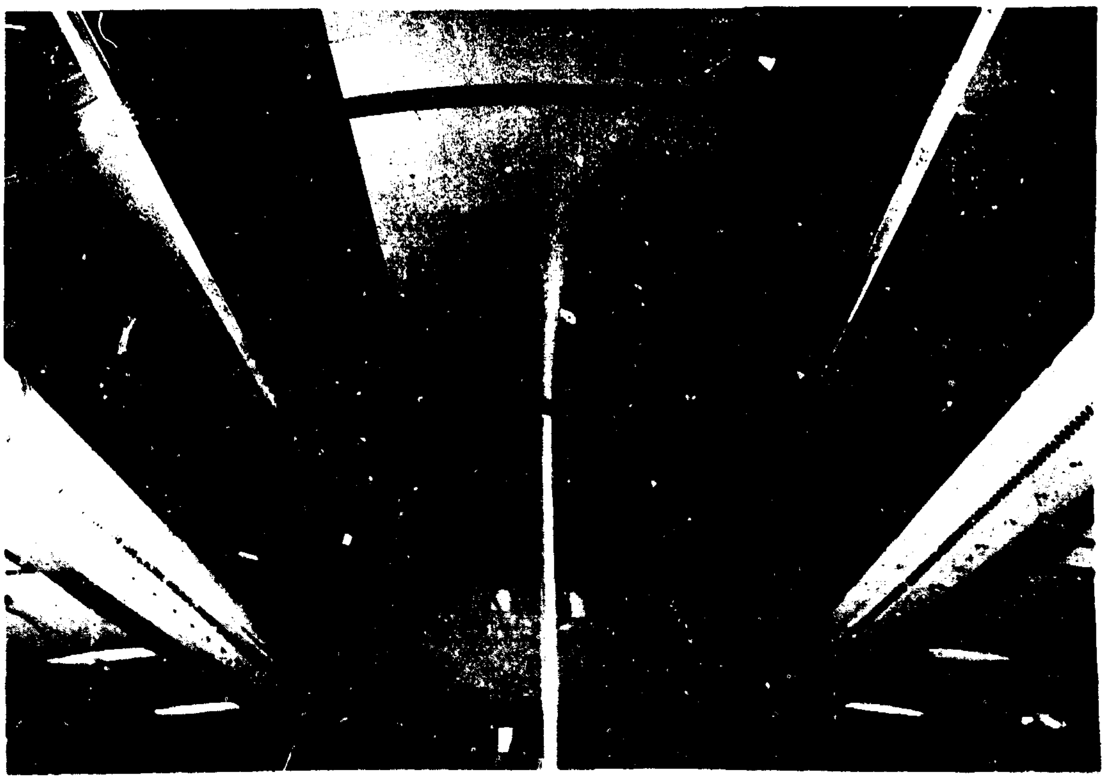

Fig. III-12 Cabin Environmental Control Tests - Partial Ceiling Perforation

1203 Hydraulic Power and Utility Systems

A cost and weight study of a dual hydraulic brake system utilizing a primary electrical command control and secondary mechanical control system has been initiated. The purpose is to provide improved braking control and lower pedal forces. Following completion of the weight and cost study a complete reliability analysis will be made.

A study is under way to devise a method of incorporating a mechanical lead circuit in the lateral control master servo to improve the airplane's roll control characteristics.

Several methods of improving the pump inlet pressurization system are being studied. They include combinations of boost pumps and bleed air reservoir pressurization and boost pumps alone. The purpose is to provide sufficient inlet pressurization for all operating conditions with minimum back pressure on the return lines.

The thermal and hydrolytic stability tests of the most promising fluids will be rerun because the thermal bombs used were found to be constructed of chrome vanadium alloy steel instead of stainless steel. Since the vanadium steel alloy is vulnerable to attack by most fluid base stocks, an attempt to plate the cylinders will be made. If successful, the new tests will begin on August 23.

The fluid loop tests have been further delayed because of discovery of defective parts in the pump used in the Castrol loop system. Teardown of the ETO-525 loop pump produced similar results. The Castrol loop pump has been refurbished with parts from the spare pumps and now has 250 hours of running time. The ETO-5251 loop pump has been returned to the vendor for repair.

One hundred thousand cycles on the rotary seal test have been completed. The temperature range was -40°F to +375°F. Total leakage across the high pressure seal was 20cc; none on the low pressure seal. The series is being repeated with the objective of achieving a total of 200,000 cycles on the seals.

Actuator number 1 in the high temperature test system rig was torn down because excessive leakage at spiral seal (15 percent graphite filled teflon) occurred. The spiral seal will be replaced by a step-cut solid ring of the same material. The seal had 4-million cycles at shut down. The polym er SP seals in Actuator number 2 have 3-million cycles and the leakage rate has stabilized at 35cc per minute. The objective of this test is to demonstrate twelve-million cycles with a leakage rate not greater than 200cc per minute.

1204 Control Systems

Efforts to reduce the power requirements for the horizontal tail surfaces are continuing. Progress has been made in reducing aerodynamic hinge moment requirements. However, there are indications that the system stiffness required to prevent tail flutter is the controlling factor in determining control system size.

The dominant factor in the system stiffness is the fluid bulk modulus. An increase in piston area is the most obvious means of improving hydraulic stiffness. Investigation is continuing to find a method of improving overall system stiffness with minimum increase in power required.

Bertea Products Company was visited to discuss progress on the development actuator program. This coordination meeting resulted in a decision to simplify the actuation linkage for valve stabilization and the SAS inputs. The concepts being examined are discussed in Bertea Monthly Progress Report Number 5, a copy of which is being forwarded.

1205 Electrical Systems

(1) DISTRIBUTION SYSTEM WEIGHT

A study has been initiated to establish an optimum location for the electric power control center for reduction of generator feeder and distribution feeder weight.

(2) ESSENTIAL POWER SYSTEM

A study has been established to determine design requirements for essential loads for the fuel system, air conditioning system, other critical load and the essential power system during smoke removal procedures.

(3) VARIABLE SPEED CONSTANT FREQUENCY (VSCF) SYSTEMS

During the month of July the following suppliers conducted symposiums and presented evaluation data on VSCF and conventional electric systems.

- Sundstrand Aviation Corp. -- Sundstrand presented the results of a comprehensive study on constant frequency electric systems. This study established a common baseline for comparison of VSCF and conventional systems with respect to performance, operating costs, and weight.
- Lear-Siegler, Inc. -- Lear conducted an operational demonstration of the cycloconverter type VSCF at Boeing, Seattle.

- Westinghouse Electric -- Westinghouse discussed the pros and cons of VSCF and conventional systems during a recent visit to Boeing facilities.

Supplier Test Monitoring and Evaluation

At the invitation of suppliers, Boeing provides personnel to witness and assist in conducting evaluation tests of VSCF systems at the supplier's facilities. During the first quarter, tests were witnessed at General Electric and AiResearch Manufacturing Division of Garrett.

(4) WIRE STUDY PROGRAM

Work accomplished on the wire study program includes the following:

a A definition of the temperature zone for wire usage on the SST.
b Coordination with wire manufacturers.
c Review of Boeing and government wire specifications to determine if existing specifications are adequate or if new specifications will be required. It appears that some new specifications will be required.

(5) GROUND RETURN BONDING TEST

Part I of the electric terminal-titanium humidity-temperature cycling test has been completed. This test, covering a 90 day period, was accomplished with tap water. Additional humidity-temperature cycling tests with a mild salt solution in the chamber are scheduled to begin 2 August 1965. The most significant results to-date are that both aluminum terminal-to-titanium junctions in the test setup failed during the 90 day period. The other terminals, nickel-plated copper and tin-plated copper, are in good condition physically. The bond resistance value of the tin-plated copper terminal-to-titanium junctions, however, are slightly higher than would be expected for a bond to aluminum structure.

1207 Automatic Flight Controls

The effects of radio altimeter and localizer antenna location on the performance of autopilot coupled approaches and landing are being investigated to find how various antenna locations may effect coupler design.

In the case of the radio altimeter antenna location, it has been concluded that good landing flare dynamics can be ensured for any antenna location provided the location is known when system gains are selected. However, the system gains which are required when the antenna is located significantly forward or aft of the CG, particularly those of pitch and pitch rate, may not be compatible with other autopilot modes and could possibly require gain changing or switching.

Further studies are therefore required to ascertain all the effects the location may have on the autopilot computer design.

Analog computer studies are being continued in the case of the localizer antenna location to find how higher coupler gains than previously used in the presence of a varying antenna location may effect tracking performance.

1208 Flight Deck Installation Systems

Layouts have been prepared and mockup studies have been conducted to explore the feasibility of reducing the forward windshield glass area without excessive compromises to the space required by the instruments on the forward panel. The studies show a possibility of reducing the windshield glass weight in trade for reduced volume forward of the panel. Since this reduction in volume results in less design flexibility for accommodating possible controls and instrumentation revisions, these factors are being reviewed before committing to a design decision.

Layouts are being prepared to establish the mounting requirements of the overhead panel equipment.

1210 Navigation

Preliminary radiation patterns have been made for the ATC-1 antenna (bottom centerline station 770) and the DME-2 antenna (bottom centerline station 358). Analysis indicates that these locations provide adequate coverage.

Preliminary evaluation of the experimental space frame radome (Fig. 5-12, D6-17488-6, June progress report) indicates an increase in side-lobe power, significant broadening of the main beam and losses of 5 to 6 db on insertion of the frame.

1211 Electronics -- General

The electronic equipment list, mentioned in the June progress report, Paragraph 5A8, is being revised to be in consonance with TWA and PAA 707 and 727 equipment. This list will be used for obtaining pricing information from the avionic manufacturers as well as establishing a basic configuration.

Schematic diagrams describing what is included in each system are being prepared. These diagrams will show the interfaces with other systems or equipment.

1213. Passenger and Cargo Provisions

Design refinement of the Boeing Model 733-362 Configuration continued with the following accomplishments:

(1) Anthropometric studies were completed and the optimum contours of the passenger cabin cross-section were established.
(2) The upper aft cargo compartment was increased in size. Its revised volume is 930 cubic feet as compared to 780 cubic feet.
(3) Emergency evacuation studies were started to determine the best locations for exits and type of assist equipment required.

13. PROPULSION SYSTEMS

1302 Air Induction System

(1) INLET TEST AND ANALYSIS

(a) Takeoff Performance Testing

The current test series to define inlet takeoff configurations with inlet internal debris deflectors was completed. The source of the high maximum to minimum total pressure distortion at zero airspeeds shown in Fig. 4-2, Page 107, of the June report was investigated. The regions of low pressure of one or two of the 64 probes were found to be very localized. The model was built with sharp-edged longitudinal structural members between the takeoff openings, which caused a local corner separation. The local corner separation problem will be examined at a later date when configuration studies further define details of the door arrangements.

(b) High Speed Performance Tests

The Mach 2.55 design centerbody for the current high-speed inlet model was tested, which completed the preliminary inlet geometry studies. The inlet performance is very close to design goals, and with vortex generators on the cowl and centerbody, the distortion is well within engine limits. The 2.55 inlet test data showed a recovery of 91.81 percent with a 4.1 percent distortion and 8.4 percent bleed at critical. At the inlet operating point, 2 percent supercritical recovery, the data showed 89.8 percent recovery with 7 percent distortion and 7 percent bleed. The model is now being used for inlet control signal studies. Further performance testing will continue when the model is modified to include bypass doors (in the subsonic diffusor) and inlet mounting struts.

(c) Upstream Distortion Tolerance Test

The testing of the two-dimensional inlet model with a fixed slot in the supersonic section of the inlet just upstream of the throat was completed. The flow from the slot was throttled externally with an exit plug in the air ducting from the slot. With the inlet operating at critical, the slot exit plug was opened and the tunnel Mach number

decreased until the inlet unstarted. A Mach number tolerance of 0.07 was obtained with 5 percent supersonic bypass from this fixed slot with no change in inlet geometry. Recovery was down 3 percent with the slot bypassing, but was unchanged with the flow closed off. From the preliminary investigation it appears that it may be practical to accommodate free stream Mach number variations by means of supersonic bypass (i.e., .05 Mach number variation due to 50 ft./sec. gust velocity).

(d) 1/5 Scale Model Design and Testing

Design studies have been carried out during July to examine ways of building a 1/5-scale (approximately 11-inch lip diameter), variable diameter centerbody. The initial studies and test samples of variable segments have shown encouraging results and the model design is proceeding. Model completion will be late in 1965. The 1/5-scale model will be primarily tested in the 18 by 18 inch propulsion supersonic wind tunnel to be operational in November 1965. This tunnel has the capability of rapidly varying Mach number, angle-of-attack, and tunnel total pressure during a run. For low supersonic Mach number and transonic testing, the larger 4 by 4 foot and 8 by 12 foot tunnels will be used.

(e) Test Schedule

The air induction system test schedule through September is shown in Fig. III-13.

1303 Air Induction Control Systems

Plans are being made to bench test three off-the-shelf inlet control components both dynamically and in steady state. The components to be tested are a normal shock positioner, a centerbody positioner, and a restart sensor. These components will be available from Hamilton Standard by November 1, 1965. When the bench tests are completed, the components will be installed for control tests of the 1/5-scale, variable geometry inlet model. A coordination meeting was held in July between Boeing and Hamilton Standard to plan the test program.

1305 Propulsion Installation

A one-day meeting was held with the General Electric designers to discuss some preliminary schemes for the nozzle secondary air system which General Electric is starting to design. The discussions also covered basic fire protection philosophy and the pod ventilation and drain system.

1306 Fuel System

The detail fuel bladder cell specification has been released to obtain supplier proposals.

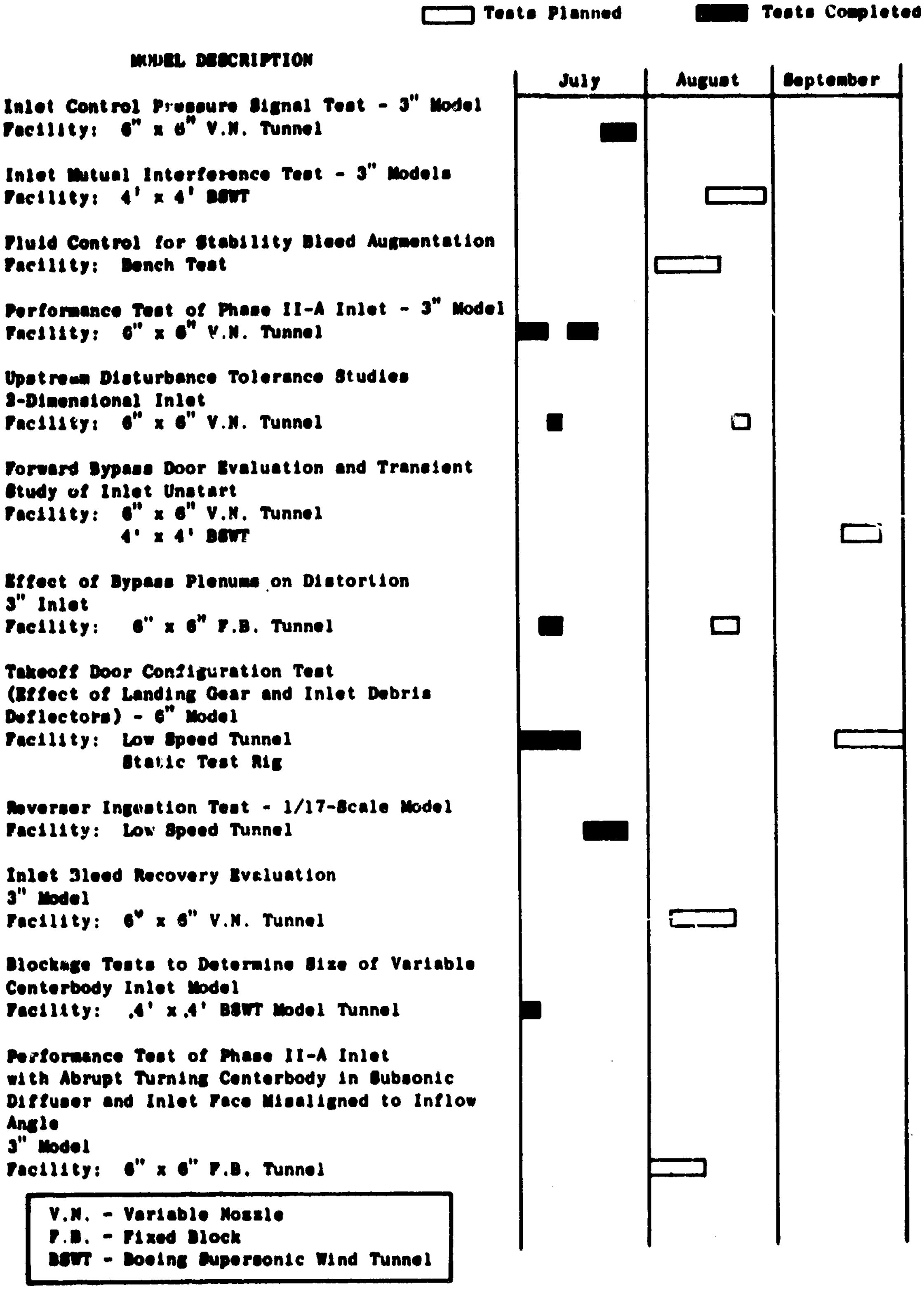

Fig. III-13 Air Induction System Test Schedule

1307 Exhaust/Reverser System

The reverser ingestion test began July 12 and has been completed. Several cascade configurations were tested to establish the speed at which inlet ingestion occurs. Figure III-14 shows the model installed in the low speed tunnel. High temperature air and steam were used to simulate exhaust flow with suction applied at the inlet. The data from the tests are currently being analyzed.

1308 Noise (Propulsion)

Nine 1/8-scale ejector-type exhaust nozzles were tested to determine the effects of ejector throat diameter and exit diameter on jet noise generation. The General Electric "star-shaped" nozzle as well as a standard round nozzle were used as primary nozzles for these tests. The acoustic data are being analyzed.

1309 Engine Coordination

(1) PRATT & WHITNEY

A meeting with Pratt & Whitney representatives from the Florida Division was held at Boeing to discuss the inlet program and acquaint them with the Boeing inlet concept and status. P&W agreed to supply updated inlet distortion criteria, attempting to account for extent and severity of radial and circumferential distortion patterns. Updated Boeing inlet distortion data will be supplied to P&W for their use in this study.

Engine-inlet compatibility studies were also discussed with emphasis on a simplified representation. A meeting is scheduled with the Simulation Group of P&W Florida Division to determine mathematical models to be used and data to be furnished by each company.

(2) GENERAL ELECTRIC

A meeting was held with General Electric representatives to discuss engine-airplane schedules, engine-airframe contractor coordination plan for Phase II-C, and engine installation problems.

The engine-airframe contractor coordination plan as proposed by Boeing was reviewed with GE. General agreement was reached as to format and scope. The definitions of responsibilities and the responsibility matrix were discussed. Additional effort and further coordination meetings will be required to complete the detail plan.

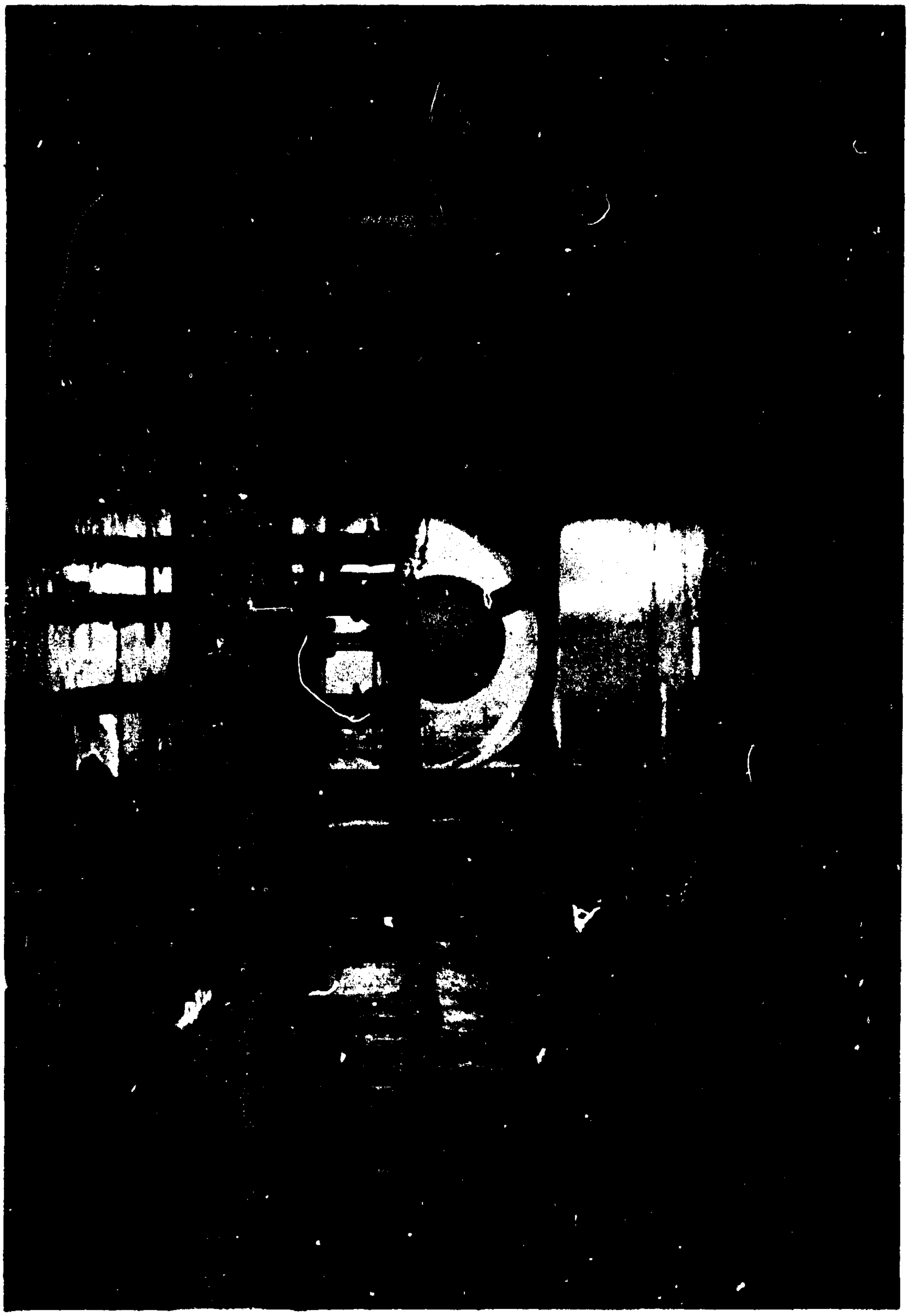

Fig. III-14

IV. AIRLINE COORDINATION

Comprehensive research and development facility tours and SST design status briefings were held with executives of Qantas and Air Canada. Tours through the SST display area and SST briefings were given to personnel from TAA, AA, UAL, SAA, JAL, DLH, TAP, SAB, AF and Varig.

Following are Airline Coordination Records covering the Qantas and Air Canada visits. No significant comments were made by airline personnel during the other tours and briefings.

S.N.Weiner
W.C.Becker
Air Canada File

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: AIR CANADA DATE: July 9, 1965

HELD AT: BOEING DEVELOPMENTAL CENTER, SEATTLE

PARTICIPANTS: J. T. Dyment, Chief Engineer

Boeing Personnel:
A.T.Burdo
S.N.Weiner

GENERAL:

Tour of propulsion test, structures test, wind tunnel and SST mockup. General discussions of SST design considerations.

SPECIFIC COMMENTS BY AIRLINE:

1. SST should be completely stable in its own right--without stability augmentation.
2. Air Canada now using in-flight automatic reporting of system integrity as aid in trouble shooting and maintenance. Now using 140 recorder channels in ten airplanes with eventual buildup to full 270 channel reporting. Believe SST should have complete system reporting of rate of change or malfunction, so replacement-repair can be planned during next stop or maintenance report. Made strong plea for weight of this recorder to be included in OWE. Would like to see new techniques developed for trouble shooting which would pin point equipment in trouble. This would preclude present random replacement methods.
3. Will require more accurate fuel gaging system.
4. Third entry door configuration and associated passenger service facilities arrangement were considered best SST arrangement Mr. Dyment had seen.
5. Air Canada DC-8 flight decks allow either pilot to handle any emergency by himself. Wants SST to have same capability.

BOEING POSITION ON AIRLINE COMMENTS:

1. Objective is to make airplane safe to fly without stability augmentation. Stability augmentation; however, provides means of preventing pilot fatigue and increasing passenger comfort.
2. Present Boeing SST design incorporates current state-of-the-art avionics for reporting system operating parameters. Requirement for degree of reporting and recording will be subject of airline standardization program.
3. This requirement is recognized and system design recognizes this requirement.
5. Will be item for consideration in airline standardization program.

S.N.Weiner
W.C.Becker
Qantas File
SST Dist. "A"

BOEING SST

AIRLINE COORDINATION RECORD

AIRLINE: QANTAS DATE: July 1, 1965

HELD AT: DEVELOPMENTAL CENTER - BOEING SEATTLE

PARTICIPANTS:

R.J.Ritchie, Deputy Gen. Mgr.	S.N.Weiner
P.W.Howson, Director, Tech. Services	J.R.Gannett
Murray Mansill, Resident Rep.	H.J.Bostrom

GENERAL:

Tour of propulsion and structural test labs, wind tunnel and SST mockup. General discussions of SST design considerations.

SPECIFIC COMMENTS BY AIRLINE:

1. Would like complete duplication of controls (i.e., nose wheel steering and speed brakes) on copilot's side so that procedures for operation of aircraft can be identical for either seat location and copilot transition to captain is simplified.
2. Suggests consideration of automatic speed brake extension during landing roll, perhaps actuated by main gear oleo compression. Believe such a system could have prevented only 707 incident suffered to date which resulted in nose gear damage.
3. 500,000 pound gross weight airplane appears too large for Qantas routes.
4. Require capacity for normal mail load escalated from 5000 pounds being carried on 707's today.

BOEING POSITION ON AIRLINE COMMENTS:

1. Will be item for consideration in standardization program. Could be made an optional feature as handled in 707 series airplanes.
2. To be studied by design project engineering.
3. Will be integrated into economic studies of other routes than the basic North Atlantic which is initial SST program consideration.
4. Requirement noted for integration with other design parameters in continuing configuration development program.

V. RELATED BOEING RESEARCH AND DEVELOPMENT

A. MATERIALS AND PROCESSES

1. Metals

(a) RESISTANCE SPOTWELDING OF TITANIUM 6Al-4V

Machine settings have been developed for making Class "A" (i.e., cast weld nuggets) spotwelds in the .060/.060, .090/.090, .125/.125, and .250/.250 thickness combinations of annealed Ti 6Al-4V. The results of the single spot shear, tension pullout, and impact tension tests on annealed-welded material are listed below:

PROPERTIES OF SPOTWELDS IN ANNEALED Ti 6Al-4V (CLASS "A" WELDING)

THICKNESS	TYPE OF TEST	AVERAGE	VARIATION	TENSION/SHEAR RATIO *
.060"/.060	Shear	4791	.033	-
.060"/.060	Tension Pullout	964	.135	20.12%
.060"/.060	Impact Tension	27.6	.181	-
.090"/.090	Shear	7480	.080	-
.090"/.090	Tension Pullout	1983	.083	26.51%
.090"/.090	Impact Tension	58.8	.255	-
.125/.125	Shear	10252	.049	-
.125/.125	Tension Pullout	3362	.057	32.8%
.125/.125	Impact Tension	91.2	.4[illegible]	-
.250/.250	Shear	29667	.067	-
.250/.250	Tension Pullout	10473	.050	35.30%
.250/.250	Impact Tension	182.5	.504	-

The same series of tests are currently being run on these thicknesses for the following weld-heat treatment sequences:

Sol.H.T. + Weld + Age
Sol.H.T. + Age + Weld
Sol.H.T. + Age + Weld + Age

* The values noted exceed the minimum allowable averages established for Ti8-1-1 and are above the requirements for the applicable military specifications.

V. Related Boeing Research and Development (continued)

(b) FUSION WELDING OF Ti 6Al-4V

Three 1/2 inch thick panels have been welded to examine the susceptibility of weld metal to the slow bend cracking test in salt water. One panel was welded with the dual electrode process (no filler wire), and one each with the following fillers:

- Commercially pure titanium
- Ti 5Al-2 1/2 Sn ELI

These panels were x-rayed and stress relieved. The "V" notch precrack specimens have been machined to test both the weld metal and heat-affected zone.

(c) NEW TITANIUM ALLOY DEVELOPMENT

Ti-5Al-3Mo-1V-2Sn and Ti-6Al-2Mo plate are currently being fabricated from commercially produced 750 pound ingots of each alloy. These experimental compositions were selected from the literature for further metallurgical and processing evaluation because of their attractive strength-toughness properties and their anticipated resistance to room temperature salt environmental failure.

Forging the 12 inch diameter ingots of Ti-5Al-3Mo-1V-2Sn and Ti-6Al-2Mo to a 2 1/2 by 10 inch cross section was accomplished from initial temperatures of 2075°F and 2150°F, respectively. A portion of each forged bar was subsequently rolled to 1/4 inch plate using three rolling sequences:

Sequence A - No cross rolling, i.e., 90 percent reduction in one direction.

Sequence B - Maximum cross rolling, i.e., 70 percent reduction in one direction followed by 67 percent reduction in the normal direction.

Sequence C - Partial cross rolling, i.e., 81 percent reduction in one direction followed by 41 percent reduction in the normal direction.

These schedules were selected to determine the influence of cross rolling on mechanical property directionality and thereby provide a basis for minimizing mechanical anisotropy.

Transverse and longitudinal tensile and precracked Charpy impact tests indicate a minimum in the directionality of each alloy when rolled according to sequence B (See Fig. V-1 for Ti-5Al-3Mo-1V-2Sn and Fig. V-2 for Ti-6Al-2Mo).

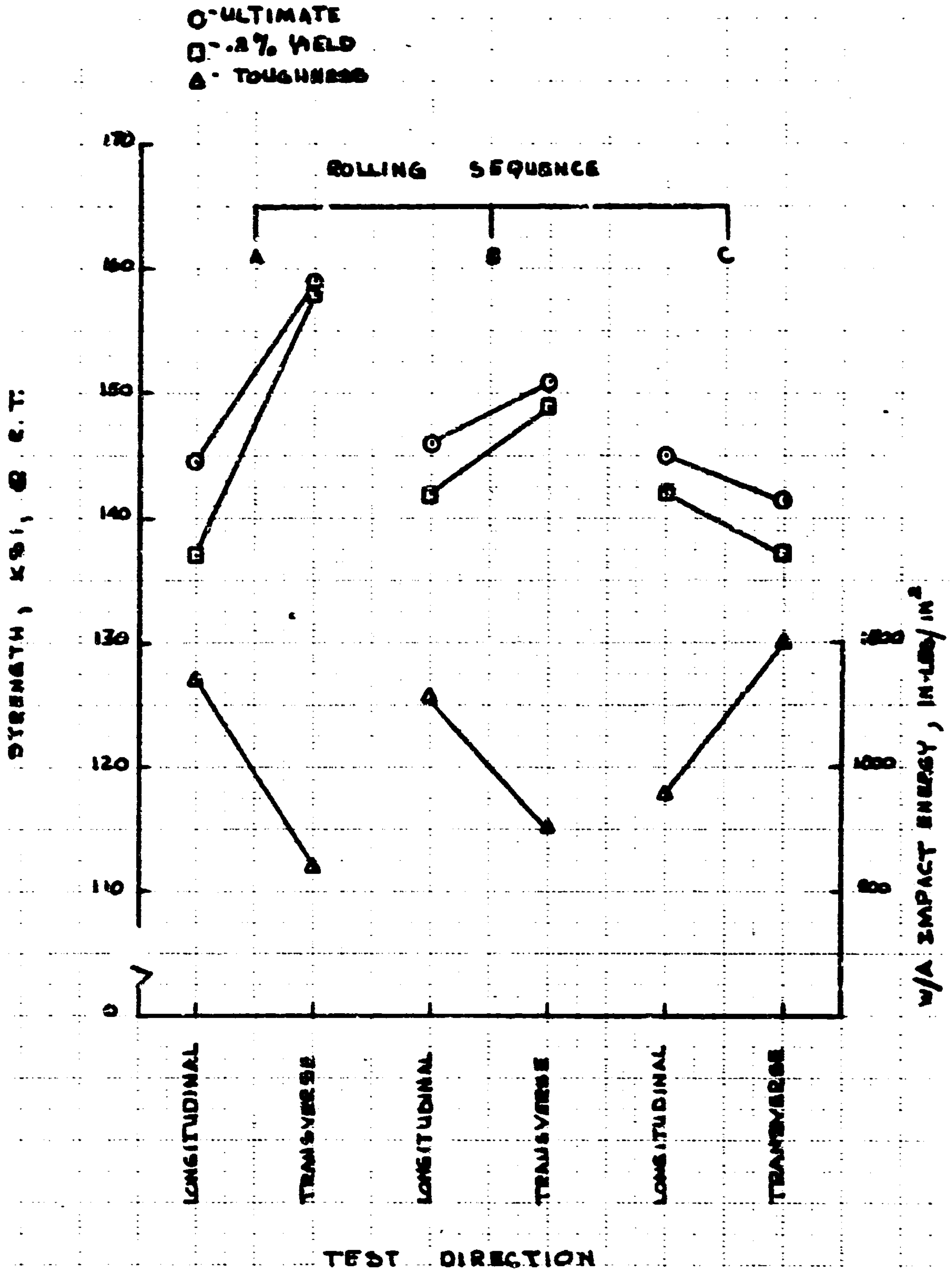

Fig. V-1 Effect of Cross Rolling on the Anisotropy of Ti 5 Al–3Mo–1V–2 S_n Plate

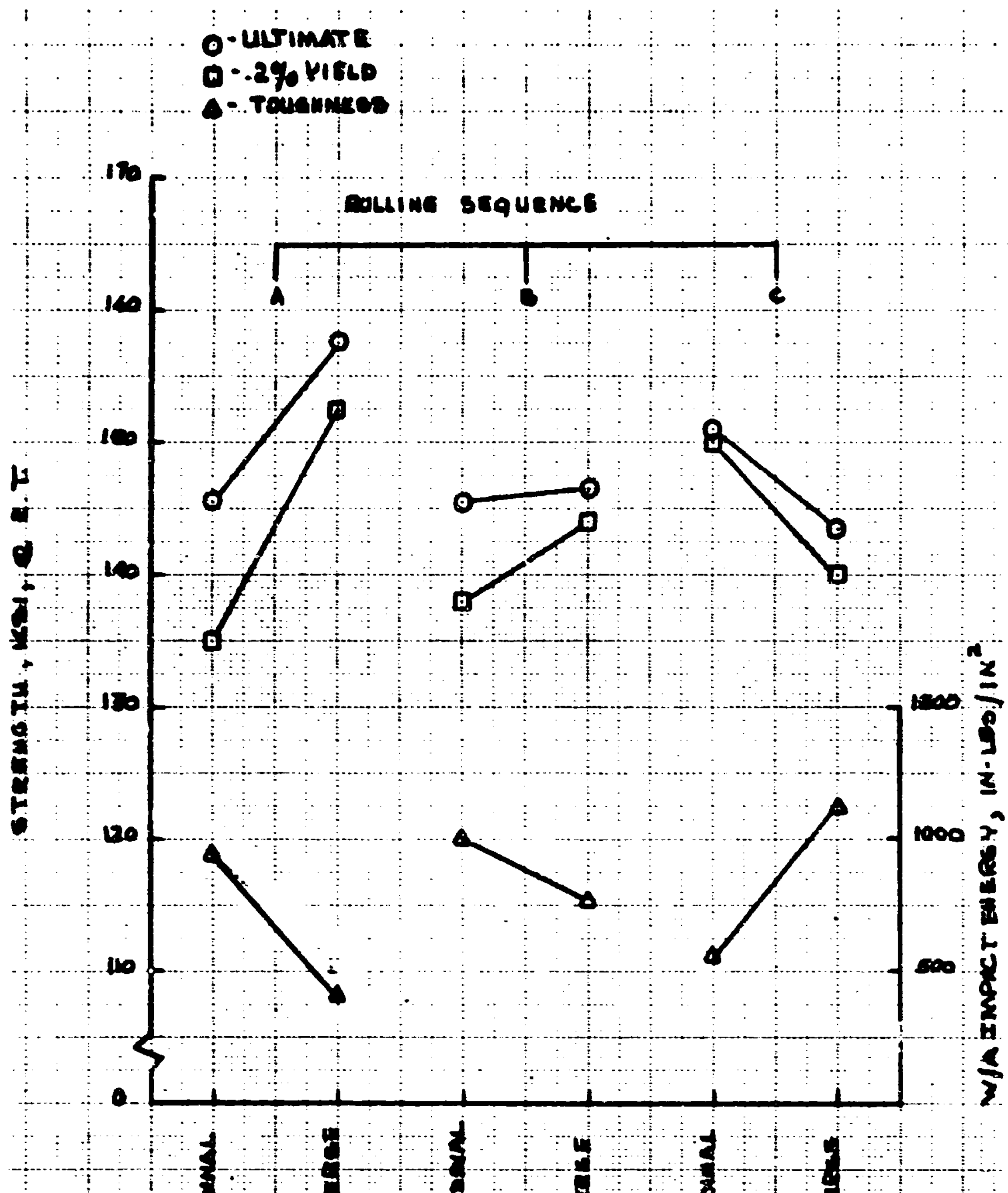

Fig. V–2 Effect of Cross Rolling on the Anisotropy of Ti 6 Al–2 Mo Plate

D6-17488-7

V. Related Boeing Research and Development (continued)

(d) Ti-6Al-4V HEAT TREAT STUDY

Heat treatment variables of Ti-6Al-4V, including solution treatment and aging temperatures, are being studied to determine their effect on strength, toughness, and environmental resistance. The strengths of each heat treat condition have been determined at -65°F, room temperature, and 450°F. The toughness properties are being determined with slow bend precracked Charpy specimens at room temperature and -65°F. Environmental resistance as determined by the reduction in Charpy toughness by 3.5 percent sodium chloride solution is being measured at room temperature. All specimens were machined from 1/2 inch thick plate. Preliminary test results are shown in Table V-A that follows

(e) HIGH TEMPERATURE STRESS CORROSION

New results from exposure tests indicate that the high temperature stress corrosion problem in titanium alloys may not be as serious as was formerly believed. Results of this test indicate that most laboratory exposure tests are much too severe for actual SST conditions. Detrimental corrosion products, if formed during the 2.5 hour SST flight, apparently will react to form harmless products upon subsequent short time exposure to low temperature.

Alternate immersion exposure tests have been completed in which the frequency of the salt water cycle was varied. These tests provide a comparison between steady state and alternate immersion testing. After these exposures there was no drop in mechanical properties with any of the test conditions as shown in Fig. V-3.

It has been established that there is a serious decrease in mechanical properties of Ti-8Al-1Mo-1V under similar steady state test conditions. A plausible explanation for the difference between the cyclic and steady state results is that the detrimental corrosion product is reacting with water in the air during the room temperature exposure of the cyclic test. This explanation agrees with NASA observations. NASA observed that X-ray diffraction peaks from $TiCl_2$ gradually disappeared when exposed at room temperature and completely disappeared if exposed to water. Consequently, it appears that time at room temperature, as well as time at elevated temperature, is important in the establishment of valid SST environmental test conditions.

(f) FASTENERS -- RIVETS

Inconel 718 is being evaluated as a rivet material. Initial driving tests have indicated that 1/4 inch diameter rivets of this material can be cold headed satisfactorily. Shear strength of the particular material used was approximately 115 ksi.

Work is continuing on the development of a hot driving procedure for 6Al-4V titanium rivets. Shear testing of A286 and 13V-11Cr-3Al titanium rivets, after various temperature exposure periods, is continuing.

Table V-A Ti-6Al-4V Heat Treat Study

HEAT TREATMENT	Test Temp (°F)	Ultimate Strength (ksi)	0.2% Yield Strength (ksi)	Elong. % (1" Gage)	R.A. (%)	Precracked Charpy* (K_{Ic})	Environmental** Charpy (K_{Ic})
1725°F/30 min/WQ	RT	164.1	149.9	10.3	19.0	63.7	50.7
1250°F/4 hrs/AC	-65°	181.6	169.1	8.0	17.7	57.5	
	450°	130.3	107.2	15.0	51.3		
1550°F/2 hrs/WQ	RT	162.3	147.8	10.7	19.5	75.6	45.2
1000°F/4 hrs/AC	-65°	182.5	170.0	7.7	16.0	85.1	
	450°	130.3	104.0	12.7	36.3		
1550°F/2 hrs/WQ	RT	171.1	147.3	9.7	17.0	70.5	47.6
875°F/4 hrs/AC	-65°	190.7	170.4	7.0	12.0	58.8	
	450°	138.5	102.7	12.7	28.0		
1325°F/8 hrs/FC	RT	156.9	142.6	12.0	26.0	74.8	52.7
to	-65°	175.2	163.0	10.3	17.7	70.4	
1000°F at 100°/hr	450°	125.6	100.6	15.7	39.0		
1550°F/30 min/WQ	RT	148.8	134.9	13.0	28.0	75.1	52.0
1250°F/4 hrs/AC	-65°	166.6	156.1	11.3	24.3	69.6	
	450°	117.0	94.1	15.0	44.0		

*All toughness values are conservative compared to surface flaw specimen data.
**Highest average value showing little or no susceptibility to environmental cracking.

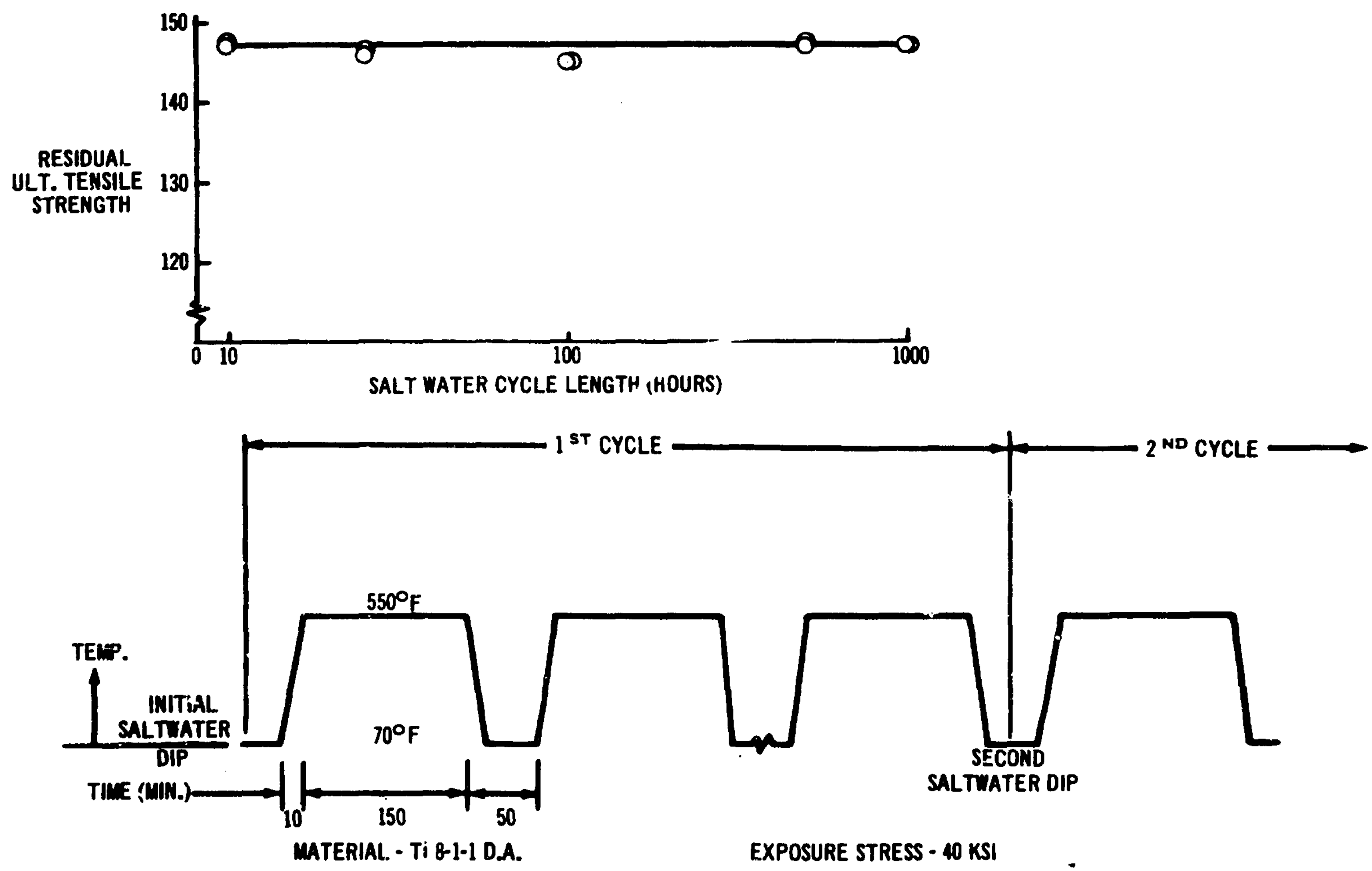

Fig. V–3 Effect of Water Cycle Frequency

V. Related Boeing Research and Development (continued)

(a) ADHESIVES

Polyimide adhesive FXM-34B-25 has reached 3000 hours of heat aging on anodized titanium lap-shear specimens. Shear strength retention as a percentage of control (initial) strength is shown below along with actual shear measured at room temperature in pounds per square inch:

Aging Temp (°F)	Shear/Control Strength (%)	Shear (psi)
500	90 to 100	2000 to 2400
550	60 to 80	1500 to 1600
600	25 to 30	600 to 700

The shear strengths of the control specimens were unusually low this time (2000 to 2600 psi vs a normal range of 2800 to 3300 psi), which casts some doubt on the initial quality of these bonds or the testing procedure. Later data will be needed to confirm or correct the present trend.

Polyimide adhesive FXM-34B-20 has now reached 6000 hours of heat aging on both anodized and phosphate-fluoride treated titanium lap-shear specimens with the following results (analagous to the foregoing -25 data):

On phosphate-fluoride treated titanium:

Aging Temp (°F)	Shear/Control Strength (%)	Shear (psi)
400	60 to 70	1500 to 1800
500	40 to 50	1000 to 1400
600	0	0

On anodized titanium:

Aging Temp (°F)	Shear/Control Strength (%)	Shear (psi)
400	50 to 60	1400 to 1500
500	55 to 60	1400 to 1800

These results reflect heat-aging at sea-level oxygen concentration which is several times that encountered in supersonic flight environment. Steps are now being taken to initiate a heat aging program at reduced pressure to evaluate this effect.

The XA-3901 silane primer previously reported as successful on anodized titanium was further tested over several surface treatments prior to bonding with FXM-34B-25 adhesive with the following results:

- Anodized: improvement of moisture resistance was confirmed as good.

V. Related Boeing Research and Development (continued)

- Phosphate-fluoride: improvement of moisture resistance was very similar to that on anodized titanium.
- Pasa Jell 107: reduced moisture resistance (without silane primer Pasa Jell 107 produces a bond with moisture resistance about the same as that of anodized or phosphate-fluoride treated surfaces primed with XA-3901)
- HNO_3: HF etch only (no conversion coat): very little resistance to moisture or heat. Reaffirms need for conversion coat prior to bonding. Priming does not obviate this requirement.

In each case where moisture resistance was improved by the primer heat resistance was retained within the duration of the test. The XA-3901 silane primer is apparently incompatible with a Pasa Jell 107 treatment and is no substitute for a conversion coat over an etched titanium surface.

(b) TEMPERATURE RESISTANT SANDWICH

A honeycomb core sandwich panel was constructed using glass fabric reinforced polyimide skins with excessive resin in the ply next to the core to act as an adhesive. The adhesive used in prior panels contains metal particles resulting in parts electrically unsatisfactory.

Climbing drum peel and long beam bending tests were conducted on the panel. The average peel strength was 3 inch-pounds per inch width. This value is approximately 20 percent that realized using an adhesive. In beam bending, skin failures occurred at 38.3 ksi skin stress at room temperature and 34.6 ksi at 300°F.

(c) HEAT RESISTANT REINFORCED PLASTIC CORE

Three types of polyimide core materials are now being evaluated in this program. They are identified as HRH-324-1, HRH-342-2, and HRH-324-3. Another honeycomb core recently incorporated into this program and currently being tested is a polyarylene ether phenol coated with polyimide resin. It is designated HRH-28-2. The test values for these materials, to date, are listed below.

Core Type	Temp.	Aging Time (hrs)	Shear Strength, psi L Direction	Shear Strength, psi W Direction	Modulus, psi L Direction	Modulus, psi W Direction
HRH-324-1	RT	0	198	66	12,870	2,590
HRH-324-1	400°F	0.5	179	61	10,620	2,180
HRH-324-1	500°F	0.5	167	57	9,710	2,040
HRH-324-1	550°F	0.5	163	55	11,010	1,880
HRH-324-1	400°F	100	175	62	12,090	2,290
HRH-324-1	500°F	100	175	57	11,930	2,030
HRH-324-1	550°F	100	160	53	13,080	2,070
HRH-28-2	RT	0	234	119	11,850	5,660
HRH-28-2	500°F	100	124	66	6,960	3,000

Each value represents the average of 5 test specimens. All values are corrected to 4.0 pounds per cubic foot density and all tests were conducted at the temperature at which the specimens are heat aged.

(d) POLYIMIDE LAMINATE AND SANDWICH SEALING

A high temperature fuel resistant material is being sought to reduce the porosity of polyimide laminates. Eighteen materials have been tested and sixteen have been found not suitable. Two materials, Viton Cement 328 and EC 1937 appear promising and were tested for fuel permeability. Initial tests at 250°F using MIL-J-5161E, Type II fuel and refluxing conditions showed no measurable leakage for Viton cement and an average permeability of 0.0033 fluid ounces per 24 hours per square foot for EC 1937. Additional laminates sealed with these two materials are currently being tested to check initial results.

(e) TEMPERATURE RESISTANT LAMINATES

Average tensile strength of polyimide laminates at 400°F and 500°F have been measured as 35,200 psi and 39,000 psi respectively. These are the first test results from an extensive temperature aging program.

(f) TRANSPARENT ENCLOSURES

The polyimide bonded edge attachment test specimens have been completed and initial testing has begun. To date, there have been no failures in the polyimide adhesive. Initial tests have shown a strong tendency toward failure at the bolt holes in the fiberglass at 900-1,000 pounds per inch of width. This tendency will be stopped by bonding aluminum doublers to the edge attachments. Two specimens have failed in the chill-tempered glass at loads of very nearly 1,000 pounds per inch which is a 5,000 psi tensile load in the glass. Since the expected strength of the glass is 20,000 psi, it is assumed that the 600°F post cure of the adhesive has degraded the glass strength. Several specimens have suffered spontaneous glass failure while lying unstressed on a workbench several hours after completing 100 hours of 600°F aging.

(g) INTERIOR WALL PANELS

Responses to requests for data about thermoplastic sheet materials indicate that the information which is needed for fireproof materials is not available from the manufacturers, and will have to be determined by company testing.

(h) FUEL CONTAINMENT

- EC-1937 and Viton cement were tested as fuel barriers when impregnated into the reinforced plastic skins of honeycomb panels. The results were the best yet obtained except for stainless steel foil. Viton

cement samples leaked at the first of the test but soon stopped. One sample of EC-1937 did not leak at anytime while the other had a very small rate during the entire test.

- Results have been obtained for the first conditioning cycle on sealants using the test apparatus to simulate flexing fuel and temperature conditions. The sealants that are in test were used to seal test plates which were then placed in the test fixture to simulate shear loading at room temperature and -65°F. The test plates were then conditioned for three days in MIL-J-5161E Grade II followed by four days at 400°F in a nitrogen atmosphere. The shear loading was then repeated. Of the six sealants reported last month, two have failed and tests are continuing on the other four. RW-193-51 Viton tape failed after shear loading at -65°F and EC-5106 cracked during the conditioning cycle. The other four sealants are 3M's EC-2332 and Dow Corning's Q94-002, Q95, 500, and Q94-501.
- Compression-deflection curves have been obtained on all the fluorocarbon and fluorosilicone compounds. For the fluorosilicones, Hadbar's compound 1000-8 appears superior with Dow Corning's LS-X30330 and Parker Seal's L-375-7 compounds next best. For the fluorocarbons, Parker Seal's 77-545 and Plastic and Rubber Products 975-75 exhibited the best compression-deflection curves. Creep characteristics were determined on all the fluorocarbon and fluorosilicone compounds. Plastic and Rubber Products compound 1133-60 showed the lowest creep of all the fluorosilicones with Stillman's TH-1057 next best. Of the fluorocarbons, the Plastic and Rubber Products compound 975-75 had the best creep characteristics while Stillman's SR276-70 was second best.
- After 21 days at 450°F, three of 15 test rivets in a fastener seal test displayed slow leakage; however, after an additional seven days at 400°F only one rivet of the original three leakers exhibited any leakage. Then after an elapsed time of 14 days at 400°F, the remaining rivet appeared to have sealed. A check after 21 days at 400°F revealed all rivets were completely sealed. The test will continue until a majority of the rivets show leakage.

(i) FUEL TANK INSULATION

EC-1974, Minnesota Mining and Manufacturing insulation coating, has been applied by hot, airless spray to hardware required for two test programs. Experience thus gained has provided additional insight into process and equipment requirements for the satisfactory application of EC-1974 to the interior surfaces of wing integral fuel tanks. A notable improvement over the results of previous spraying operations was evidenced. It is felt that increased familiarity with spray unit characteristics along with the development of skilled operators will contribute significantly to the feasibility of the process. Continuing improvement and modification of the spray system to better adapt it to anticipated requirements will also be of benefit.

Items which were insulated are as follows:

- Three 10 by 30 inch titanium panels to be used in an insulation adhesion and fatigue test (Material thickness of 0.35 inch nominal).

V. Related Boeing Research and Development (continued)

- A 24 by 24 inch lid, approximately four inches deep which will be bolted to a test tank for environmental and fuel coking tests (Material thickness of 0.375 inch, nominal).

After the EC-1974 cure cycle was completed, insulation surfaces were sanded lightly and four coats of EC-1937 elastomeric top-coat were applied by brush.

The insulation adhesion panels will be tested in tension and compression at working and limit load levels. Test temperatures will be 70°F (control), 450°F, and -65°F. Specimens tested at 450°F and -65°F will be subjected to alternate fuel and elevated temperature exposure before test and at intervals of 20,000 loading cycles. Specimens will be loaded for a total of 100,000 cycles or until failure.

In the environmental and fuel coking test, the effects of fuel exposure and of temperature and pressure cycling will be determined on the insulation. There will also be inspections to determine the presence and extent of deposits occurring as a result of coking of the fuel at elevated temperatures.

(j) TITANIUM EMITTANCE CONTROL PAINTS

The Boeing letter requesting SST exterior paint samples has had the following response.

Submitted samples	5 vendors
Will submit samples	4 vendors
Will not submit samples	5 vendors
No answer	38 vendors

Dow Corning has been solicited for a sample of their catalytic cure silicone. This step has been taken in order to have a promising resin on hand for Boeing formulation work in the event that vendor coatings do not satisfy the requirements.

Conical mandrel bend tests of Midland's black silicone applied over various surface treatments on Ti-8-1-1 yielded the following results:

Surface Treatment	Anchorage Capability
Vapor Blast	Best
Boedize	
Dry Blast	Average
Chromic-Sulfuric Acid Anodize	
Chromic-Nitric Acid Conversion*	

*NOTE: Semco Sales and Service Inc. proprietary treatment Pasa Jell 107

Surface Treatment	Anchorage Capability
Phosphoric Acid Anodize	
Alkaline Clean-Acid Etch	Minimum
Phosphate-Fluoride Conversion	

The Midland paint film was relatively hard at 400°F, but had poor room temperature flexibility. Studies of paint film anchorage to titanium alloy surface treatments will be continued when a paint material is available which possesses both adequate 400°F hardness and good room temperature flexibility.

(k) CORROSION INHIBITOR COATINGS

Base line failure curves of precracked Charpy V-notch specimens both in air and in salt water have been determined on a new apparatus for testing corrosion inhibitor coating effects. An equivalent load level was found $\frac{K_{i(environment)}}{K_{ic(air)}} = 0.77$ which differentiated well between the resistance to failure of precracked specimens in salt water and air. Testing at this level in salt water resulted in failure in 1.6 minutes while loading in air was discontinued after 300 minutes with no specimen failure. These "baseline" results will be used to guide testing of precracked specimens coated with candidate inhibitor finishes.

B. MANUFACTURING DEVELOPMENT

1. Manufacturing Process Development and Refinements

(a) ELEVATED TEMPERATURE SHEET METAL SECTION FORMING

The elevated temperature sheet metal section rolling program has progressed as follows: The 46 rolls necessary to stage the return "Z" section are installed. During the last week of July, initial tests of the facility will be performed. Effort is being made to solve the problem of galling and seizing experienced in the hot draw bench forming. Additional lubricants and die materials are being investigated. Initial tests making 2t bends using a hot brake punch were successful. A six foot tool having an integrally heated punch and die and auxiliary radiant heat has been designed to form return "Z" section.

(b) RESISTANCE HEATING FOR SECTION STRETCH FORMING

Tests performed while simultaneously heating a stretch form die block and resistance heating the section to be formed indicate this process to be feasible. Additional evaluation of the proper die block temperature is required.

(e) HOT PRESS SIZING

A hot press sizing manual detailing the current state-of-the-art capability is scheduled for release on July 30, 1965.

2. Manufacturing Experience and Physical Data on Full Size Assemblies

A sketch of each item of method development hardware and its relation to the airplane has been attached (Fig. V-4) for reference.

Sketch 31: The manufacturing plan is in work.

Sketch 32: A revised Engineering advanced material release was issued on July 7, 1965.

Sketch 33: Tools and details are in work. The assembly of the 30 by 60 inch high temperature bonded strake panel is scheduled for completion August 6, 1965.

Sketch 34: The 30 by 110 inch leading edge slat is currently in planning and tool design. Some details have been released for fabrication.

Sketch 36: The wing strake body attachment is progressing in tool design and detail fabrication.

Sketch 37: The 9.5-inch diameter window reinforcing ring has progressed to the welding phase. Hot sizing for weld distortion removal and cleaning are the subsequent operations required to complete this assembly.

Sketch 38: The overall manufacturing plan is being finalized for the 60 by 230 inch large bonded strake panel.

C. QUALITY ASSURANCE DEVELOPMENT

1. Fusion Weld Inspection System

A major effort of quality control research and development has been the development of an automated system for the inspection of fusion welds. The confidence level testing phase of this development is in process. Prelimi[illegible]y information shows that a combination of in-motion x-ray and ultrasound could be used for the determination of subsurface defects. Weldments up to 1/8 inch thick can be inspected with in-motion x-ray using inspection exposure rates comparable to the welding rate, thereby allowing the inspection equipment to use the same fixtures as the welding equipment.

Preliminary results indicate weldments greater than 1/8 inch thick can be economically inspected using ultrasound. Welding fixtures

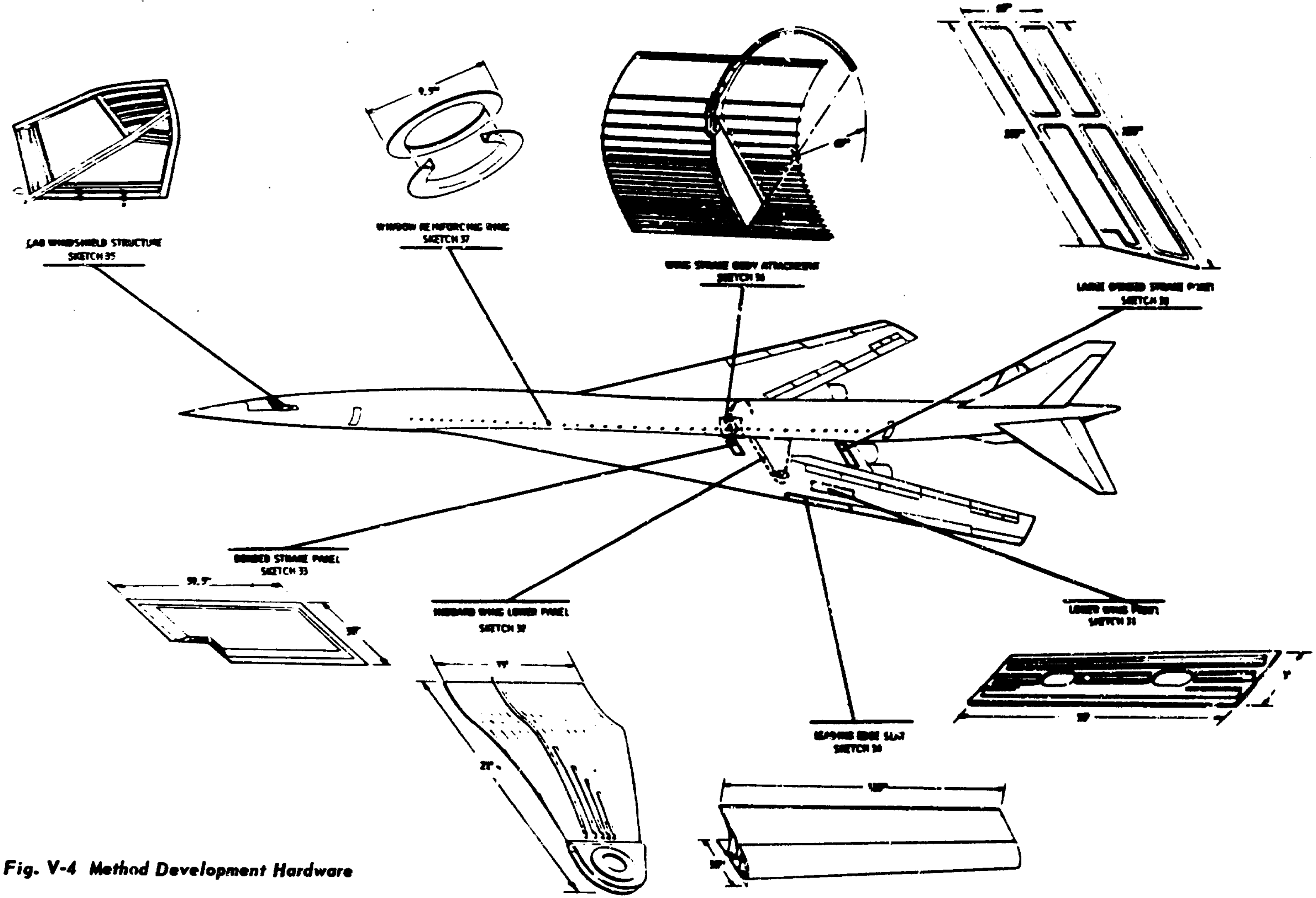

Fig. V-4 Method Development Hardware

with one or more transducers, as shown in Fig. V-5, could be used according to the weldment thickness. One transducer would be used for weldments up to 1/4 inch thickness, and two transducers for welds up to 1/2 inch thick. Welds greater than 1/2 inch thick would use three transducers for inspection.

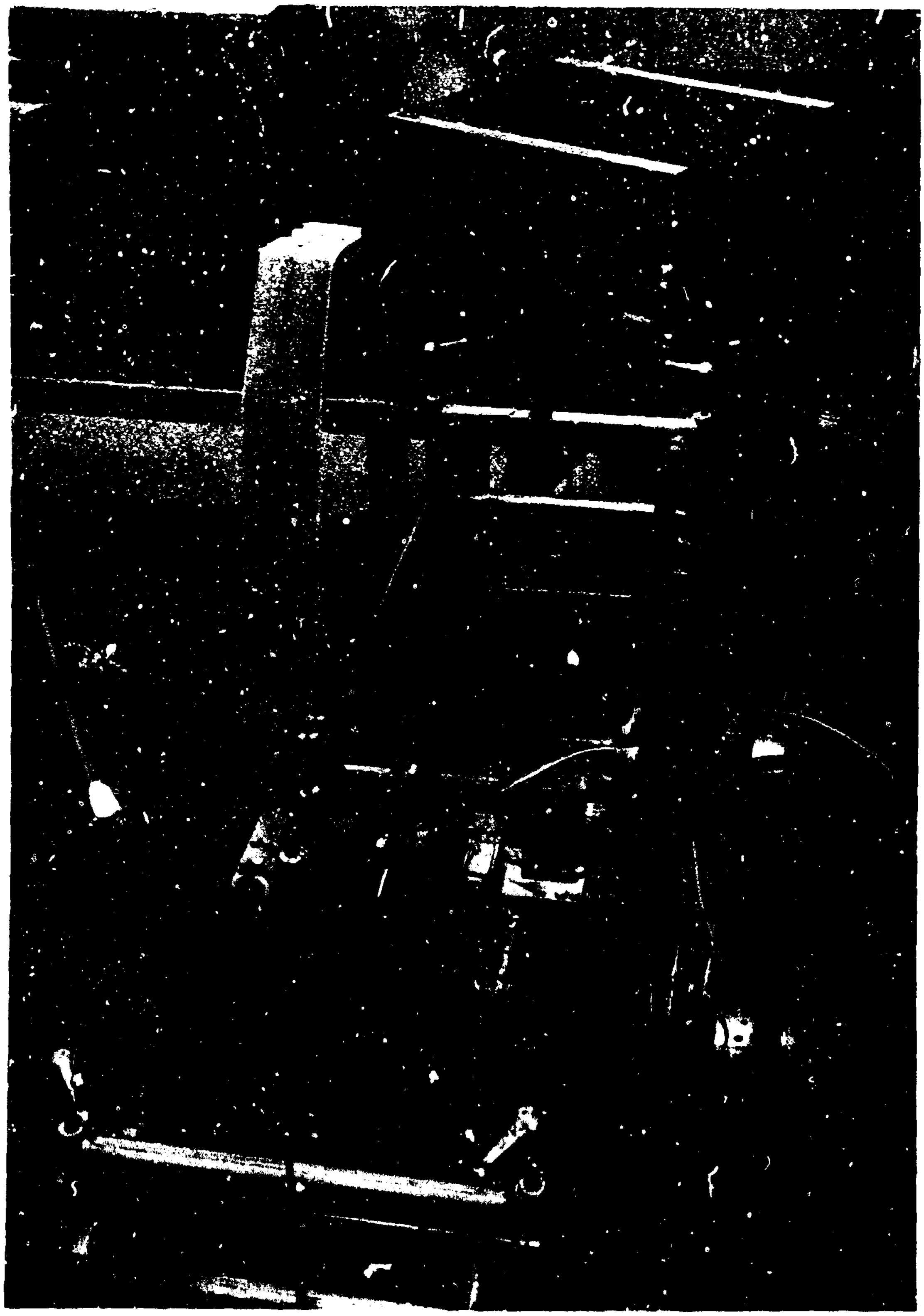

Fig. V-5 Ultrasound Inspection - Weld Fixture

VI. STATE OF THE ART DEVELOPMENT

A. INTRODUCTION

The Boeing Company engages in extensive company financed research activities, international contacts, membership on national committees, and active participation with the U. S. government on many programs. Boeing maintains its technical state of the art posture by the activities of the following representatives and groups within the company:

1. Boeing Scientific Research Laboratories

BSRL is an independent group of World-renowned specialists doing basic research in the fields of flight sciences, mathematics, plasma physics, solid state physics, and geo-astrophysics. This group of researchers report direc tly to Mr. George Schairer, Vice President, Research and Development. They are available at all times for consultation on problems of immediate concern. A report of their activities* is issued semi-annually to all technical staffs. In addition BSRL invites recognized specialists from the free world scientific community to lecture to the Boeing technical staff. Titles of these lecturers are also shown in the Review.

2. Boeing International

This branch of Boeing handles all of the company's business outside the continental United States. Boeing International has a technical data exchange program with Dassault Inc. of France, and with the German Firm of EWR-Boelkow in which the company has a financial interest. Boeing has a permanent staff of engineers in Munich working with EWR on programs such as supersonic fighters, assault transports, V/STOL, and helicopters. This group reports technical developments to the corporate New Product Development Technical Staff on a weekly basis. In addition, Boeing International collects abstracts and sends to the Company divisions compilations of European technical documents. These European abstracts are sent to all technical staffs on a monthly basis. Another source of technical information is a compilation of abstracts from Soviet and East European technical journals. This compilation is also sent to all technical staffs on a monthly basis.

3. Boeing Technical Library

The Boeing Technical Library receives all documents published by NASA and is notified of publication of technical documents through the NASA Scientific and Technical Information Facilities. Another major data source is the Defense Documentation Center. Boeing receives compilations of the technical development objectives in specific technical domains of Air Force interest. These reveal both today's SOA and AF objectives. The AF recognizes the SST program and releases technical information funded and supported throughout the defense community. Boeing also has access to the DOD Specialized Information Analysis Center. An example here is the Defense Metals Information Center at

*Copies of BSRL activity reports and other documents, abstracts, accession bulletins, etc., referred to in the following paragraphs can be made available to the FAA if desired.

Batelle Memorial Institute, Columbus, Ohio. This center reviews all literature, intelligence, etc., issues SOA reports, technical memos, and special technical notes. They are also available for consultation. All of these abstracts and report lists are sent to Technical Staff on a monthly basis.

The Library also publishes an accession bulletin on a weekly basis and these bulletins are circulated to all members of the technical staffs.

4. NASA and DOD Technical Committees

NASA has solicited the aid of recognized experts in the many disciplines of aeronautics and space through a series of Research Advisory Committees. These committees meet on a regular basis for two or three days. The agenda generally consists of NASA technical personnel reporting on research of current interest to the committee, the industry, armed forces, and other Government members reporting items for their areas, and then a specific discussion on research areas where NASA should increase or decrease their efforts. Boeing's top technical managers are represented on several of these committees. For example, William T. Hamilton (Aircraft Aerodynamics), William H. Cook (Aircraft Operating Problems), Howard Smith (Fatigue and Research Technology), and Harold Hayden (Aircraft Structures), are currently represented. A compilation of all reports submitted at these meetings is circulated to all technical staffs.

Several members of Boeing's technical management also serve on advisory committees to the DOD and the resulting technical exchange is reported similarly.

5. Engineering Society Technical Committees

Boeing technical personnel serve as members and committee chairmen on almost all of the committees of the AIAA, SAE, ASME, AHS, etc. These people review the manuscripts of forthcoming technical articles before they are published in the journals of these societies. They also screen prospective papers and arrange the technical sessions of the National meetings of these societies. Individual papers, and/or compilations are made available to the technical staffs.

6. Technical Staff Research Units

All divisions reporting to Group Vice-President E. C. Wells maintain technical staffs in the areas of aerodynamics, structures, propulsion, avionics, flight controls, and mechanical equipment (systems). These technical staffs all have separate research groups with a primary responsibility of developing new methods, and new fundamental approaches. The various research groups are fully cognizant of the areas in which the company is working and maintain up to date technology through an established need-to-know on such projects as C-5A, AMSA, CX-6, ADO-12, FX, Minuteman, MOL, VOYAGER, SATURN, and commercial airline projects. Some examples of technical staff research work underway to maintain Boeing

state-of-the-art are given below.

It is the responsibility of the Chief of Technology, SST to see that the SST project is fully aware of the research work being continuously carried out within and without the company. Specific research items are reported from each of the technical staff areas as they are pertinent to the SST.

B. STATE-OF-THE-ART RESEARCH

1. Aerodynamics Staff

(a) BOUNDARY LAYER RESEARCH

- Skin friction at speeds up to M ≈ 5; available data are being correlated with a recent theory advanced by Coles. A preliminary estimate using the Coles method indicated a potential reduction on the order of 10 percent in the estimated skin friction at high Mach numbers.
- The effects of flexible surfaces; an analytical and experimental study is underway on the effects of a flexible surface in reducing skin friction.

(b) WING-BODY AERODYNAMICS

- Two-dimensional airfoils with high critical Mach numbers; a continuing program to develop improved airfoils is under way.
- Wing-body at subsonic speeds; an attempt is being made to develop a theoretical method for designing wing-body geometry to meet prescribed conditions.
- Wing-body at supersonic speeds; a theoretical method based on linear theory is being developed to optimize wing geometry for the pressure of an arbitrarily defined body. This work is being performed under contract to NASA.
- Sonic Boom; studies of the effects of meteorology on sonic boom propagation are continuing as well as analytical investigations of improved methods for predicting the sonic boom characteristics of a configuration. Discussions have been held with Professor Lutz in Germany concerning his ideas for the use of external burning to reduce sonic boom intensity; it appears that this will be helpful only for blunt, hypersonic shapes.

(c) HIGH LIFT SYSTEM

- Advanced techniques; a major program of wind tunnel testing and theoretical analysis is under way to develop and evaluate new concepts as well as to refine current mechanical and blown systems. A significant achievement has been the high lift system incorporated in the Boeing C-5A proposal.

- Ground proximity effects; the development of advanced high lift systems has caused renewed interest in both ground effects and proper simulation of these effects in the wind tunnel. Active programs are under way in both areas. Advanced, lifting-surface theoretical methods are being used to study ground effects. A blowing BLC approach is being investigated as a means for eliminating boundary layer build-up and separation on a wind tunnel ground plane. Close surveillance is maintained of the work being carried on by NASA, the RAE in England and others, on moving-belt ground planes.

(d) PERFORMANCE METHODS

Two optimization digital computer programs are under development which will be useful to study optimum mission flight paths. They are based on the steepest-ascent, variational technique. The work is being performed under contract to NASA.

(e) STABILITY AND CONTROL

- Variable-stability flight testing; the Boeing 367-80 jet transport prototype has been modified so that it may be used to simulate the low-speed flying characteristics of a wide range of airplanes. An on-board computer, working through the normal flight control system, the spoilers, and the thrust reversers, is used to modify the airplane's basic characteristics. A hydraulic system was used to provide artificial, computed stick-force characteristics to the copilot's seat. The airplane is being used currently, under contract to NASA, to study the low-speed handling qualities of two NASA, SST research configurations.
- Handling qualities requirements; various studies are under way to develop better methods for analyzing handling qualities and for defining the requirements applicable to large airplanes. Methods based on servo-analysis techniques appear to offer great promise. An example has been the recent use of $L\alpha/\omega_n$ versus damping ratio to define longitudinal, short-period dynamics. This approach has provided the first overall correlation of pilot opinion with a wide range of airplane characteristics, based on both ground simulation and flight test experience. Liaison is maintained with Ashkenas and other people working in the field throughout the United States.

2. Mechanical Equipment

(a) CABIN PRESSURE CONTROL

Investigations covering cabin pressure control concepts, aerodynamic effect on outlets, and physiological comfort levels are being made in an effort to provide a cabin pressure control system that represents a significant improvement over those in service at this time.

Items of interest are:

(1) Flight Test of AiResearch Prototype Electronic Cabin Pressure Control System

A flight test of the AiResearch prototype electronic cabin pressure control system has been conducted. Flight test data have been received and are being evaluated. Results and evaluation of the test will be reported in T6-3487. A complete set of data has been sent to AiResearch for their evaluation.

(2) 737 Cabin Pressure Control System

An electronic cabin pressure control system is planned for the 737 airplane. Hamilton-Standard has been selected as the supplier of this system. Development of the system is now in progress.

(3) Physiological Tolerance of Pressure Rate of Change

A study is being conducted to determine physiological tolerance to pressure rate of change so that a realistic pressure rate of change requirement can be incorporated in future specifications for cabin pressure control systems. Presently, results from subjective tests to determine pressure rate of change perception levels are being evaluated.

3. Hydraulic Fluids

- Participation in ASTM, Technical Committee "O" meeting on Hydraulic Fluids.
- Visit to NASA Lewis Research Center and Republic Aviation Company to review the NASA sponsored high temperature fluid development program. Results expected from the planned tests should supplement Boeing derived data.
- Visit to Gits Seal Co. Greatest development is in high speed rotary seal applications. Little experience in linear seal applications.
- Visit to Koppers Co. to review split ring design and materials. Koppers believe a new filled teflon material will do well in the Boeing SST thermal environment.

5. Hydraulic Fittings

Preliminary contacts have been made with the Air Force Rocket Propulsion Laboratory and North American Aviation to monitor development of the single bead welded fitting.

6. Alternating Flow Hydraulic Systems

Reports on development of alternating flow hydraulic systems sponsored by the Air Force and performed by Republic Aviation have been reviewed. The concept does not appear to offer advantages for the SST at this time and extensive hardware and system testing will be required to develop designs and establish performance characteristics.

VI State of the Art Development (continued)

7. Electric Power System Design -- Variable Speed Constant Frequency System

(a) TYPE OF WORK

A test and analysis program has been initiated to evaluate variable speed constant frequency (VSCF) systems that are currently under development by the electrical industry. This type of system does not require a constant speed drive (CSD). The regulation of frequency is accomplished electronically without rotating parts.

(b) STATUS

(1)

An industry survey of major suppliers working in this field has been completed. Data received from this survey were used to conduct inhouse trade studies to evaluate performance capability, maintainability, reliability and cost factors versus equivalent parameters for conventional CSD/generator systems. The above effort constituted Phase I of the Boeing inhouse VSCF research and development program.

(2) Test

A Boeing flight test of VSCF systems has been scheduled for initiation during September. The initial hardware for the flight test program has been received from General Electric and is currently undergoing laboratory checkout.

8. CRC-Aviation -- Fuel Tank Deposits Group

(a) TYPE OF WORK

This group of the CRC Aviation Fuel, Lubricant and Equipment Research Committee is a cooperative technical group formed to study a particular problem as described below.

(b) SCOPE

The objective of the group is to establish a test program to evaluate the formation of deposits in aircraft tanks under simulated high Mach number flight conditions, not as an extension of the previous supersonic transport program, but an expansion of the deposit study to the higher temperature range.

(c) STATUS

Organizational meeting and subsequent planning meetings were held in June and July. Test planning is started. Plans are to be reviewed by analysis sub-panel by early September 1965.

9. Flight Control

(a) GUST ALLEVIATION AND MODEL SUPPRESSION STUDIES (CAMS)

The purpose of the program is to investigate the feasibility and understand the technology involved in the use of closed loop feedback systems to suppress aeroelastic modes and to provide direct gust alleviation. Results will be applicable to any highly aeroelastic vehicle.

(b) DEVELOPMENT OF REDUNDANT SYSTEM HARDWARE

The purpose is to develop an augmentation system which is fail operational for a first failure and fail safe for subsequent failures. This system will be compatible with triple redundant electronic systems. Augmentation hardware has been developed and is currently being tested.

(c) FLIGHT SIMULATOR DEVELOPMENT

This effort has produced a control system simulator that provides a more exact simulation for better evaluation of flight control systems. Special analog comp[illegible] programs allow representation of lumped and distributed control system parameters.